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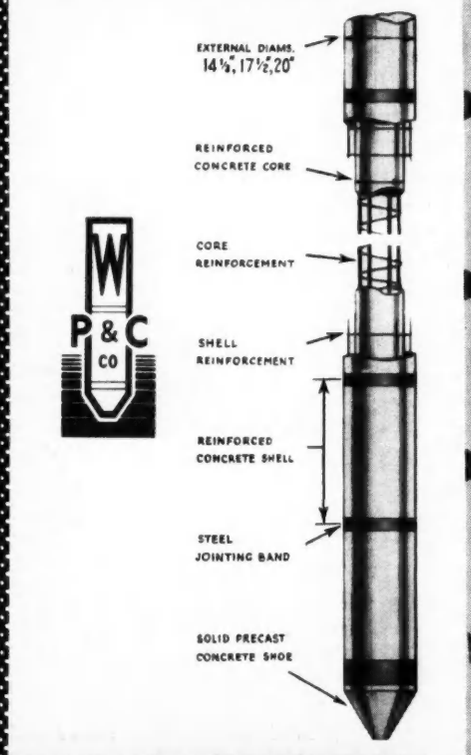

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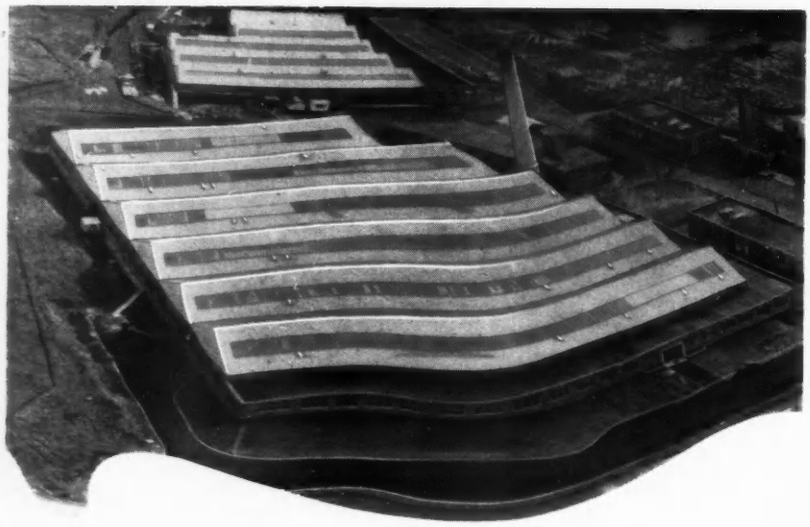

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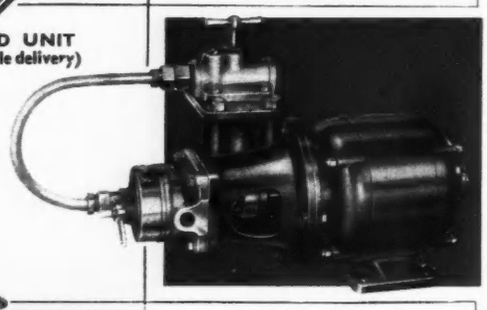

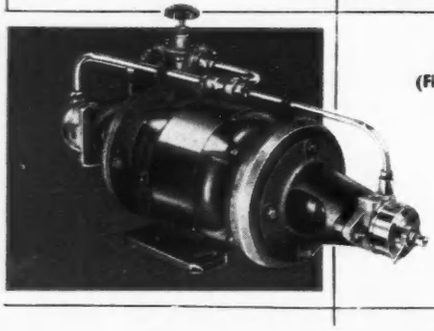

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THE ENGINEER

VOL. 203 No. 5285 MAY 10, 1957

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ENGINEERING WAGES

As we go to press, no firm decision has been reached by the engineering and shipbuilding unions about their reactions to the Reports of the Courts of Inquiry which studied the recent disputes in these two industries. However, the Amalgamated Engineering Union's national committee, whose opinions carry great weight within the Confederation of Shipbuilding and Engineering Unions, did decide last Monday to recommend that there should be negotiations with the employers on the basis of a wage increase of 11s. per week with the "strings" attached that there shall be no renewed claim for increased wages for at least one year and that the unions will use their full authority and influence to bring to an end certain restrictive and other practices regarded as objectionable by the employers. The Court recommended that negotiations should be reopened either upon that basis or upon the alternative basis of a wage increase of 8s. 6d. "without strings." It will, we think, be a happy outcome should the Confederation adopt this A.E.U. proposal, even though, about the "strings," the national committee's resolution urged that there should be efforts to obtain "modification of the terms." For, effectively, it will mean the recognition by the unions that claims for higher wages cannot reasonably be based solely on changes in the cost of living and that productivity within the industry must also be taken into account. Since even an increase of 8s. 6d. per week may well have inflationary implications, as the Courts recognised, an increase by 11s. certainly will have. It can, perhaps, be justifiably hoped that the unions will co-operate more actively than in the past in raising productivity, thus limiting the adverse effect. But it would be unwise to pin too many hopes upon the effect of a settlement along the lines recommended by the Court. For, though no direct application for higher wages could be made within a year, there are other claims that the unions could and probably will advance which might have much the same effect. They may, for example, press for a shorter working week or longer paid holidays.

The reactions, both of the employers and of the unions to certain other recommendations of the Courts are as yet quite unknown. The Court which considered the engineering dispute recommended amongst other things that there should be set up a National Joint Council "which would keep wages and related matters under periodic review . . . and which would concern itself positively with the productive efficiency of the industry." In doing so it repeated a recommendation of a Court of Inquiry that sat in 1954. At that time the unions viewed with favour the setting up of such a Council. Indeed, it was their suggestion that it should come into existence. But employers have always felt that because the negotiating machinery is so often in operation, anyway, there is no need for a Council. The employers are probably right. Yet it might be worth while to give way upon the point. For it is a fairly general experience in other fields that when a body meets regularly, even if fundamentally its two sides view problems in different lights, the heat generated by opposition is less than that occurring at an *ad hoc* meeting called because a dispute has already arisen. For those attending regular meetings become accustomed to the workings of the minds opposed to them and are not angered by encountering unexpected opposition. Under a wise chairman, respect, not unmixed with affection, is generated for men who prove capable of defending a proposition apparently of no great strength, or of probing weaknesses in what seemed, at first sight, an impregnable argument. Since in human affairs it can seldom be shown that any proposed action is absolutely right or absolutely wrong, debate amongst men well-accustomed to one another's company usually leads to wise compromises rather than to the joining of battle. If it is such a body that the Courts contemplate might be set up, it might well be worth while to give it a trial.

The Courts also drew attention to another recommendation of their 1954 predecessors. It was that "an authoritative and impartial body" should be appointed to consider "the general movement of wages, costs and prices" and "the complex and sometimes conflicting economic arguments which surround them" and to

form a view " upon the national economy . . . and to give advice and guidance as to broad policy." This recommendation is repeated. For the Courts clearly saw that there are aspects of wage disputes within industry which are not capable of being dealt with by the two sides in industry alone. Employers, for example, may stubbornly resist a wage claim on the grounds that it is not in the national interest to grant it. But the unions involved may well feel that it is not for a section of employers alone to interpret what is or what is not the national interest. The consequence is naturally the generation of much friction, since each side feels the other to be wilfully misunderstanding the case. This recommendation of the 1954 Courts encountered opposition not from the employers but from the unions, which no doubt feared that it would weaken them in their individual bargaining with employers. Yet it would unquestionably be of advantage to all concerned if the inflationary situation which has existed ever since the war could be brought to an end. The idea thus seems to us worthy of study. For it does need study if it is to be made acceptable both to employers and unions. The body concerned, if it is to have any useful effects, must not only be, in fact, impartial, but must be obviously impartial. If union suspicion of it is to be allayed, it must be independent of the Government. Nor must there be any shadow of doubt about its deliberations being over-weighted towards one side or the other. How is such a body to be created ; and by what machinery is effect to be given to its unbiased conclusions ?

THE ANTI-SUBMARINE POSITION TO-DAY

Between the two world wars, the British Government consistently advocated the abolition of submarines by international agreement. Yet a few weeks ago, when explaining to the House why we had decided on building an atomic powered submarine, the Parliamentary Secretary to the Admiralty said that marine nuclear propulsion was most immediately attractive for submarines because of the operational advantages it conferred. He was referring, it should be noted, to a submarine for the Royal Navy—a navy which, in alliance with the other NATO navies, will have the surface command of the sea. For surface ships the advantages of atomic power—with the unlimited endurance it gives at high speed—need no emphasis. But for submarines they are not so self-evident in view of the very large range of the conventional diesel-electric submarine, either on the surface or, using the snort, when submerged at periscope depth. It is, indeed, curious that in this connection such firm evidence as is available suggests that Russia is still content with the conventional type with a submerged speed—for upwards of an hour—of 17 knots. None the less, the atomic powered submarine with almost unlimited endurance and a speed of 25 knots or more, both on the surface and submerged, is now with us. What can she do that the conventional submarine cannot do ? To deal first with her offensive capabilities—she cannot make use of her high speed when attacking. Not only does her increased size make her an easier asdic target, but the hydrophone effect given off by a fast-moving submerged object is very pronounced in the asdic installation of a surface escort vessel. She can, however, and certainly will, use her high speed (and prolonged endurance) to intercept a target, escorted by aircraft, reported perhaps 100 miles distant. She will also find it much easier to make a voyage from A to B undetected, if her main object is to avoid coming within range of enemy detecting devices, as it would be if intending to lay mines or to fire a guided missile with a nuclear warhead at our towns and industrial areas. Radar does not and cannot operate under water, but the snort of the conventional submarine is no longer an effective antidote. Despite anti-radar coating, it is clearly visible in the radar screen at a considerable distance in a reasonably calm sea. Finally, far fewer submarines will be required in the pipeline when proceeding to and from a given number of patrol areas.

It is, however, when she is acting on the defensive that an atomic powered submarine gains the greatest advantage. In the '30s, an asdic installation had a range of no more than 4000 yards, and was not efficient if the ship was proceeding at more than 18 knots. Moreover, false " echoes " from rocks, shoals of fish, wrecks, &c., were almost the rule rather than the exception. The performance of present-day asdics is rightly kept top secret, but it is certainly immeasurably more reliable and efficient than in those days. It will, however, require highly efficient installations and operators, and very fast-moving anti-submarine vessels to chase and maintain contact with a submarine proceeding at 25 knots or more, 500ft deep, while she is manœuvring to evade them. And this, in essence, applies also to a submarine which has been detected by means of a dipping asdic dropped from an aircraft or by a barrage of sonobuoys dropped from a slow-moving helicopter.

It is thus clear that the weaker naval power which relies mainly on underwater craft will reap the greatest benefit from the use of atomic power for their propulsion. Submarines, it is true, are the only kind of craft which can operate effectively in waters under enemy control and proved invaluable to the Allies when they lost command of the sea temporarily in the Pacific and the Mediterranean in World War II. None the less for Britain, which is having to abandon or reduce her overseas bases for political or economic reasons, it is far more important that her surface warships should not be hampered in their operations by lack of fuel. Mr. Soames would have been more convincing if he had explained to the House that despite these considerations there were sound reasons why we should continue with the building of the " Dreadnought " submarine. Two years ago, before we had access to American experience and know-how in the construction of marine reactors and of the specialised materials required for the heat exchangers, pumps and valves, we had no alternative but to try out an atomic power plant in a submarine. Moreover, the building of a replacement programme for our cruisers is at present precluded by the financial situation and by the need for a reliable anti-aircraft guided missile. Would it in these circumstances be justifiable to throw away the money expended and the progress already made in designing and planning a submarine with this new and revolutionary kind of propulsion ?

The Engineer
100 Years Ago
(MAY 8, 1857)

" INSTITUTIONS OF ENGINEERS "

" It is with much pleasure that we call the attention of our readers to the establishment of an Institution of Engineers in Scotland. The satisfactory results of the Glasgow meeting of the Institution of Mechanical Engineers, whose head-quarters everyone knows are at Birmingham, seem to have prompted the engineers of Scotland to form a society of their own, and we cannot doubt that complete success will attend their efforts. A general meeting of the institution was held on Friday evening last at the Philosophical Society's Hall, Glasgow, when officers were elected for the first session, and the rules by which the society is to be governed were discussed. What these rules are we do not yet know, but may presume they are not very different from those which have been laid down by kindred societies. It would seem that it is the intention to model the proceedings somewhat on the plan of the Institution of Civil Engineers in London, and that weekly meetings are contemplated ; and if so, we cannot but congratulate the council upon arriving at so wise a decision. . . .

" We are glad to notice that the style of the new institution includes engineers generally, that it is not confined either to civil or mechanical. It is quite a useless distinction, as every civil engineer is more or less, or ought to be, a mechanical one, and works specially classed under those belonging to the civil engineer are frequently carried out by mechanical engineers. We would, in conclusion, specially call the attention of the Glasgow Institution to the subject of steam navigation, in which they have done so much, as a subject demanding their first consideration ; and we trust the result will show both the theory and practice of our northern friends to be somewhat different from what is professed to be the result of our experiences in this part of the world—the demonstration of the truth of the square versus the cube theory, and the loss incurred by expanding steam in marine engines."

A Seven Day Journal

Institution of Civil Engineers

THE Institution of Civil Engineers held its annual dinner on Thursday of last week at the Dorchester Hotel in London. The principal speaker was Lord Radcliffe. In proposing the health of the Institution, he compared the work of the civil engineer with that of the administrator and politician ; especially in overseas territories, he suggested, the civil engineer's work was likely to be the least criticised and the most permanent. The administrator, he noted with a hint of pathos, never expected his work to be appreciated, but a structure like the Pont du Gard aqueduct was admired even when it was in decay. The president, Sir Arthur Whitaker, replied to Lord Radcliffe's toast. Sir Arthur was of the opinion that the opportunities for civil engineers to-day were as good as at any time in the past. He was distressed by the possibility of losing good civil engineers from this country by emigration. One reason for this, he suggested, was a lack of work at home, of the kind which stirred the imagination. For instance, road engineers had not been given a chance to show the quality of their work. Professor Pippard proposed the toast to the guests, and Sir Gilbert Rennie, G.B.E., the High Commissioner of the Federation of Rhodesia and Nyasaland, replied.

Professional Engineers Appointments Bureau

THE annual report of the Professional Engineers Appointments Bureau provides evidence of the continuing demand for technological manpower. It says that a point of interest in the work during last year was the increasing number of Canadian and American firms using the Bureau's service. It is not, however, the policy of these firms to recruit from this country engineers whose experience can be described as general, and an appointment is unlikely to result where the experience of a candidate is not in some specialised field of engineering. Unless an engineer has good academic qualifications and adequate professional experience the prospect of obtaining a post before arrival in the country is not encouraging.

The report goes on to comment that the complex national situation at home has tended to encourage more people to seek the opportunities and standard of living available in Canada, the Rhodesias and other Commonwealth countries. The possibility of a larger number finding employment oversea must be recognised. The report adds that, so long as the supply of engineers remains below the level necessary to meet the increasing demands to fill outstanding vacancies at home, no opportunity should be lost to emphasise the great importance of increasing training in this country, to a point where the supply of young engineers can keep pace with the expansion of engineering at home and oversea. Despite a decrease in the number of engineers registering with the Bureau, the number placed in 1956 increased. The number of vacancies notified did not fluctuate appreciably, but a larger proportion was for senior administrative posts. The more senior appointments now attract a reasonable selection of qualified applicants, which suggests that larger numbers of more experienced engineers are considering changing their posts than a year ago. Average salaries of successful placings were higher than for previous years, and it is now difficult to find sufficient candidates from those registered who are seeking salaries much below £800 per annum, compared with past years, when it was relatively simple to fill the junior posts.

Electrical Research Association

SOME aspects of the prospective development of nuclear power in Great Britain during the next half century were discussed by Sir Christopher Hinton, speaking at the annual luncheon of the Electrical Research Association in London on May 1. Sir Christopher referred to an anomaly in the present early stage of development of the art when nuclear power generation by gas-cooled reactors demanded lower steam conditions and thereby tended to retard the development of steam turbine plant. But that was a passing phase, and, looking further ahead, one could forecast with certainty a period of marked progress. For example, within a decade technical advances, such as the use of beryllium as a canning material and the introduction of ceramic fuel elements, would permit higher working temperatures. A sober assessment of these and other improvements, leading to cheaper reactors with longer life, suggested that by 1965 electricity would be generated in Great Britain more cheaply by nuclear power stations than by orthodox coal-fired stations. Allowing for development of conventional plant at the present rate, it could be foreseen that by 1980, the cost of nuclear power generation would be about half that of electricity generated by conventional fuel-fired plant. Before the end of the century it was likely that nuclear power would be used extensively for domestic space heating in Britain ; similar developments would probably take place much earlier in Sweden, where alternative fuels were scarce. Sir Christopher also spoke of the impact of the rapidly advancing nuclear technology on slower-moving technologies. The special requirements of nuclear engineering, like those of the gas turbine, had provided the incentive for metallurgical progress which might well be useful to other industries. Of the present research effort into the peaceful uses of nuclear energy, about one-third was devoted to reactor development and two-thirds to chemical problems including purification, separation and diffusion.

Research Buildings and Training Centre

THREE new buildings for the Cement and Concrete Association at Wexham Springs, Stoke Poges, Buckinghamshire, were formally opened by Mr. Hugh Molson, Minister of Works, last week. These buildings comprise the training course, printing and canteen building, the works and services building, and the chemistry and physics laboratory. Introducing the Minister of Works, Sir Francis Meynell, the director of the Cement and Concrete Association, said that when starting seven years ago, in a tentative way, to hold training courses in concrete techniques, the Association used a rented building a little way up the road. The courses were an instant success, he continued, and there had never been an occasion when there were not more applications than available places. To mark the opening of the new training course building, a special course on road and bridge design and construction for chief officers of local authorities was held.

This two-storey building contains a lecture room, lounge, recreation room and hostel accommodation. It also houses the Association's printing and despatch departments and the kitchen and canteen premises. In the 100ft long by 50ft wide shell-roofed works and services building, practical work and demonstrations on the training courses and the construction of large-scale units required for testing are carried out. A clear height of 16ft in the building allows for the accommodation of transportable lifting gear. The two-storey chemistry and physics laboratory contains on the ground floor the offices, darkroom, workshop and stores : the general chemistry laboratory, general physics laboratory and five smaller laboratories for individual research are on the first floor. Fundamental research into the structure and properties of concrete and into methods of studying the behaviour of concrete in practice are undertaken in this department, together with a service for the design of new forms of apparatus and facilities for routine chemical analysis.

Concrete Aggregates from Fly Ash

ON May 1, the Minister of Power, Lord Mills, opened a plant at Battersea power station, which is intended to process the power station ash so that it can be used as a lightweight aggregate for concrete. The plant is claimed to be the first of its kind in the world, and is considered, although commercial, as a full-scale research plant. It is a joint venture of the Cementation Company, Ltd., and the Central Electricity Authority, and it has been built by Sinterlite, Ltd. The latter firm has developed the processes involved, which produce an aggregate known as " Terlite." " Terlite " can be graded from ¼in downwards, in the usual manner, and is claimed to be completely inert and to be advantageous for building work for various reasons.

The plant itself is fairly simple in principle. Its heart is the kiln, one to each of the dual units, measuring about 40ft high by 10ft in diameter of welded steel plate lined with refractory bricks. Each kiln has an annual capacity of some 50,000 tons of " Terlite." The ash from the power station's electrostatic precipitators is first delivered into bunkers, from which it is fed into a shallow circular " pelletiser," revolving at an angle, where it is sprayed with water. In the pelletiser, gravitational and centrifugal forces cause the damp ash to form into small balls, their size being regulated by the speed of revolution and the tilt. The pellets spill over the rim into a conveyor leading to the kiln.

The process is such that the small percentage of carbon in the p.f. ash is utilised to support combustion once the fire is kindled. The process is continuous, the pellets slowly descending from the top of the kiln until they reach the revolving grate at the base. The sintered pellets emerge to be screened, graded into sizes and stored in hoppers. The kiln temperature attains a maximum of about 1400 deg. Cent. It is hoped, we understand, that research can be carried out on the extraction of iron oxide from the p.f. ash, the collection of germanium oxide from the dust of the exhaust gases, and the recovery of waste heat from the whole process.

Supersaturation in Steam Expanding from a Low Initial Quality

By DENIS J. RYLEY, M.Sc. (Eng.), A.M.I.Mech.E.*

The following article describes, in an abridged form, experimental and theoretical work on which the writer has been engaged for about three years. Conclusions derived from experimental work by Mellanby and Kerr (1922) on supersaturated steam have been retested by further experiments and their work extended and amplified. It is shown that expanding steam will supersaturate to some extent in convergent nozzles even when the original condition is one of wet equilibrium. Both theory and experiment support the view that new condensation occurs upon liquid already precipitated, and there is evidence that severe boundary friction will encourage reversion. The results obtained may be of interest to engineers engaged on low pressure steam turbine design.

SUPERSATURATION in expanding steam has long been a subject of interest to mechanical engineers. In every decade for over half a century one may find papers bearing on the subject, yet in spite of a great volume of past work, both experimental and theoretical, the subject presents many problems which are still unsolved. The nature of the state of the steam in the " wet " region of steam turbine expansion is one such problem. The design of low-pressure blading for this region involves a certain amount of guesswork, and many designers—as the writer knows from discussions with them—guess differently. It is hoped that the work to be described in this article will throw at least some light on this problem.

Historical

In 1922, Mellanby and Kerr[1] undertook experiments on elementary convergent nozzles with straight axes in which the state point locus of the steam crossed the saturation line within the nozzle. They maintained a constant initial pressure of about 75 lb per square inch absolute with a sub-critical back pressure and they measured values of discharge over a range of initial temperature varying from saturation to about 100 deg. Fah. of superheat.

They evaluated their results broadly in the following way, making use of the diagram (Fig. 1), which is reproduced from their work. The flow curve *KLMN* is appropriate to expansion into the Wilson zone with total supersaturation, whilst *HJMN* is the curve obtained for thermal equilibrium. The common point *M* is attained when conditions of saturation are attained at the nozzle exit. The authors then add *PQ*, which is a flow curve for an efficiency, less than 100 per cent, supposed constant over the whole operating range and based on wholly supersaturated flow. They then argue that independent experiments have shown that nozzle efficiency declines with rising superheat, which would tend to cause an actual flow curve to follow a locus such as S^1RP, the slope of which increases with diminishing superheat. In the event of any departure from complete supersaturation when operating with low initial values of superheat the curve will tend to follow a locus such as *RT*, which falls below *RP*. They then describe experiments on four nozzle and search tube combinations, the dimensions of which are reproduced in Fig. 2*a*. One set of results is reproduced in Fig. 2*b*. The experimental flow curves are deemed to be of the shape S^1RT (Fig. 1), having a point of tangency at *R* with the appropriate flow curve P^1Q^1 for constant efficiency. Mellanby and Kerr then elaborate a theory of " partial reversion " in which the defect in flow, intercept *y*, which is claimed to arise from failure to achieve full supersaturation, is functionally related to the conditions of the steam and particularly to the " equivalent " wetness. Fig. 3 shows the experimental relationship thus obtained between the fractional reversion *x* and the equivalent wetness which would have been attained if equilibrium had been complete. The intercept y_1 (Fig. 1), lying to the left of *MU*, was attributed wholly to a fall in efficiency with rising superheat, and considered to be unconnected with any reversion to the right of *R*.

On their own admission the results obtained by Mellanby and Kerr were not fully satisfactory, and the discussion which followed their paper showed that the latter had not been understood. Although the general trend of reversion shown in Fig. 3 is reasonable and agrees with expectations, the relative placings of the individual curves betray anomalies. Two other matters were also unsatisfactory. In the first place, no serious attempt was made to extend the experiments into the region of initial wetness of the live steam. They did, in fact, include a few points obtained with " boiler steam " (i.e. wet, of uncertain quality), which are denoted by *X*

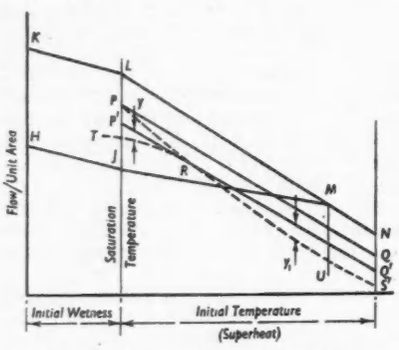


Fig. 1—Theoretical flow curves (from Mellanby and Kerr, page 86, Fig. 2)

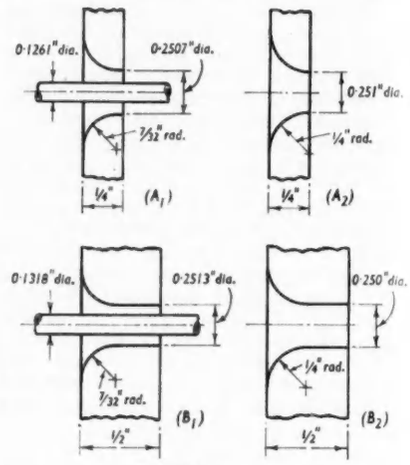


Fig. 2*a*

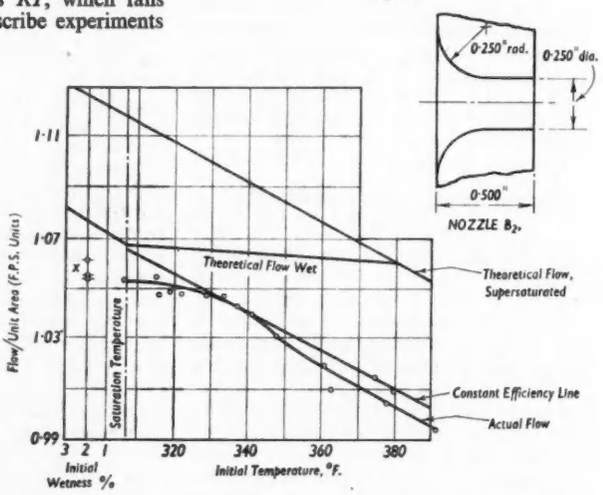


Fig. 2*b*—Flow curves for nozzle B2 (from Mellanby and Kerr, page 870, Fig. B)

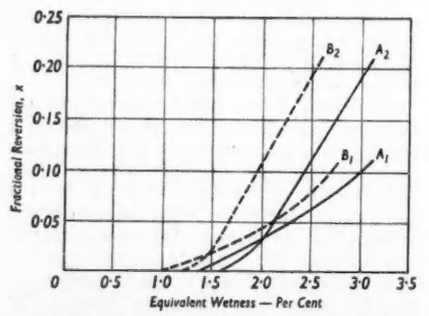


Fig. 3—Fractional reversion curves (reproduced from Mellanby and Kerr, " Proc. I.Mech.E.," 1922, Vol. 2, page 855)

Symbols

x—Fractional reversion.
q—Dryness fraction of original wet steam.
q^1—Dryness fraction after expansion from dry saturation to critical conditions.
H_R—Critical isentropic heat drop per pound for equilibrium steam.
H_S—Ditto for supersaturated steam.
T—Temperature.
w—Liquid precipitated in transit.
V—Velocity.
v_W—Specific volume of water.
v_S—Specific volume of saturated steam.
v_{SS}—Specific volume of superheated or supersaturated steam.
A—Controlling section area.
W, W^1—Mass flow.
C_D—Discharge coefficient.
m—Mass of globule.
t—Time.
K—Thermal conductivity.
r—Globule radius.
L—Latent heat.
μ—Viscosity.
C_v—Specific heat at constant volume.
l—Length along nozzle.
ρ_w—Density of water.
C_p—Specific heat at constant pressure.
R—Characteristic gas constant.

* Department of Mechanical Engineering, University of Liverpool.

on Fig. 2*b*, but these confuse the general picture. In the second place, the experimental curves are supported by far too few measurements, one curve, indeed, depending on only six readings for the entire range. The state of knowledge, therefore, following this paper, which in this aspect of the subject is also the present state of knowledge, may be summarised thus. It is known that with low initial values of superheat some condensation may occur in a convergent nozzle, but it is not known whether, with steam initially wet, the condensation will be complete or partial. In neither case has the mechanism of condensation been investigated.

Present Experiments

In order to gain additional knowledge concerning these problems a series of experiments have been conducted at Liverpool University which are substantially a repetition of those of Mellanby and Kerr except that the range of initial quality has been extended at the lower end to include steam initially wet, and a large number of experimental readings have been taken. The present experiments were conducted using nozzles having the profiles shown in Fig. 4, the two nozzles

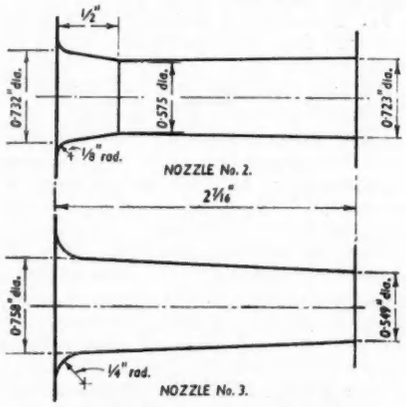


Fig. 4—Profiles of experimental nozzles

employed being members of a set of ten. Nozzle No. 3 is a wholly convergent nozzle providing a very long approach to the exit in order to secure as long a time as possible to encourage condensation. Nozzle No. 2 is convergent-divergent with a short convergence. In the present experiments the divergence serves no purpose and the nozzle may be regarded in this context as a short convergent nozzle. In all cases " search " tubes were in penetration, four tubes being available. Two of the search tubes were of smooth polished exterior whilst two others had the reproducible form of roughening shown in Fig. 5. The search tubes were not employed

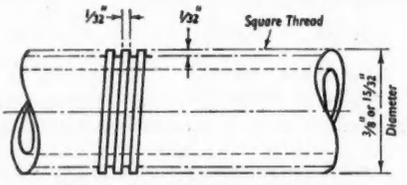


Fig. 5—Roughening of search tubes

for obtaining the static pressure distribution in the experiments under review ; they merely served to present additional boundary surface within the flow, and rods of similar dimensions would have served equally well. The experiments were conducted with a nominal initial gauge pressure of 80 lb per square inch, the exhaust being sub-critical and provided by an atmospheric condenser.

The supporting plant needs only brief description. The steam was raised in a small water-tube boiler and piped some 25ft to a gas-fired superheater. This was independently controlled and had adjustable thermostatic setting. The superheated steam was then piped a further 25ft to the nozzle apparatus, the essential features of which are shown in cross section in Fig. 6. Fine pressure adjustment before the nozzle was secured by having a large valve and a by-pass valve in parallel. Variation of initial steam quality was obtained by suitable pre-setting of the superheater. Some difficulty was encountered with the lower values of dryness fraction, which tended to fluctuate whilst a discharge test was in progress. Any test in which the temperature variation on the throttling calorimeter was within 5 deg. Fah. of the mean value, corresponding to a dryness fraction variation of 0·002, was deemed satisfactory. For tests in which this variation was not greatly exceeded, it was customary to take several readings of temperature at regular intervals and obtain an average. Such tests are ringed on Figs. 9 and 10 for recognition and as they agree well with the general trends they may be accepted as accurate.

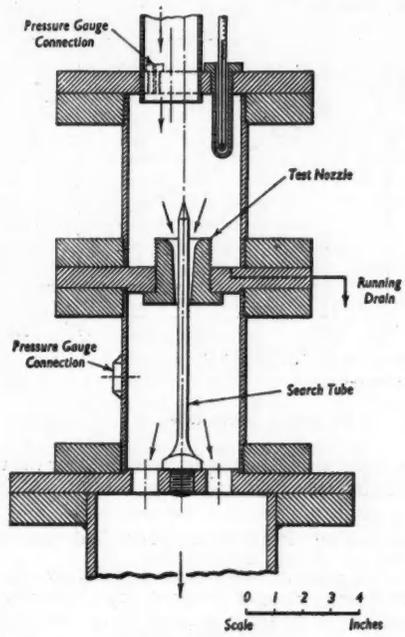


Fig. 6—Nozzle apparatus

Mellanby and Kerr worked with falling values of temperature. In the present experiments tests were taken mainly with rising values, but some control tests with falling values are also included.

For tests in which the dryness fraction is to vary the only suitable instrument for measuring dryness fraction is the time-honoured throttling calorimeter, concerning which an immense amount of practical knowledge has been accumulated by many workers. The calorimeter employed was designed specially for the present purpose and is shown in cross section in Fig. 8. It operates on the double flow principle and unlike most modern calorimeters employs a heat-insulating orifice and compression washer. (These latter were connected with a separate inquiry.)

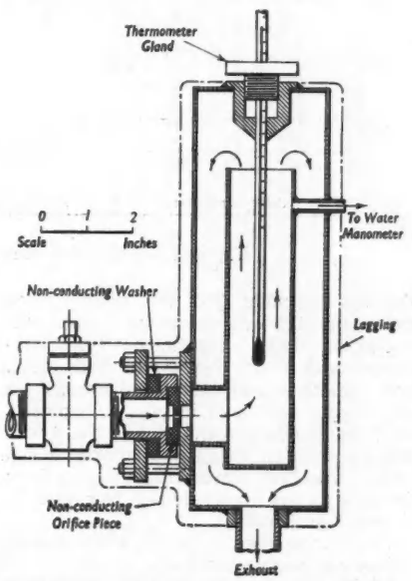


Fig. 8—Throttling calorimeter employing heat insulating orifice and steam jacketing

The B.C.U.R.A. and other recommendations with regard to sampling, radiation correction, &c., were observed. The calorimeter was found to have a quick response and was well adapted to its task.

Experimental Results

Fig. 7 shows the position of the state point loci on the heat-entropy diagram, *RS* being appropriate for saturated conditions at exit, and *PQ* and *PS*¹ being appropriate to supersaturated and equilibrium flow respectively for saturated conditions at inlet. The position of the Wilson Line as determined by various workers is also shown, and it will be seen

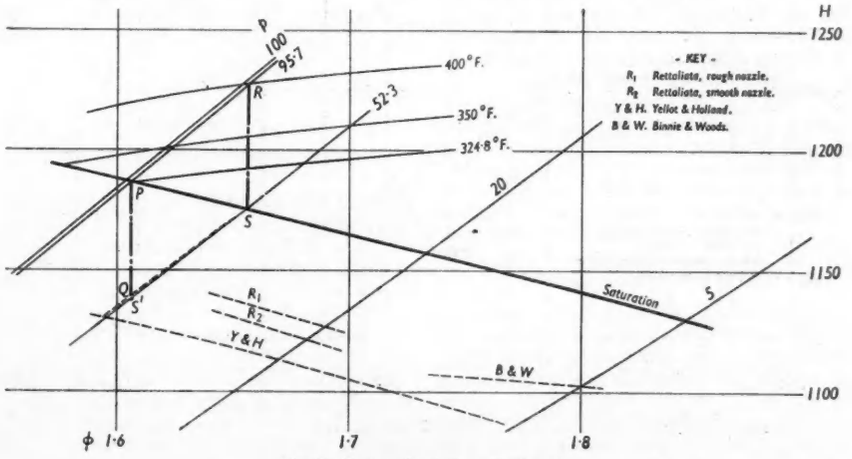


Fig. 7—State point loci and Wilson lines

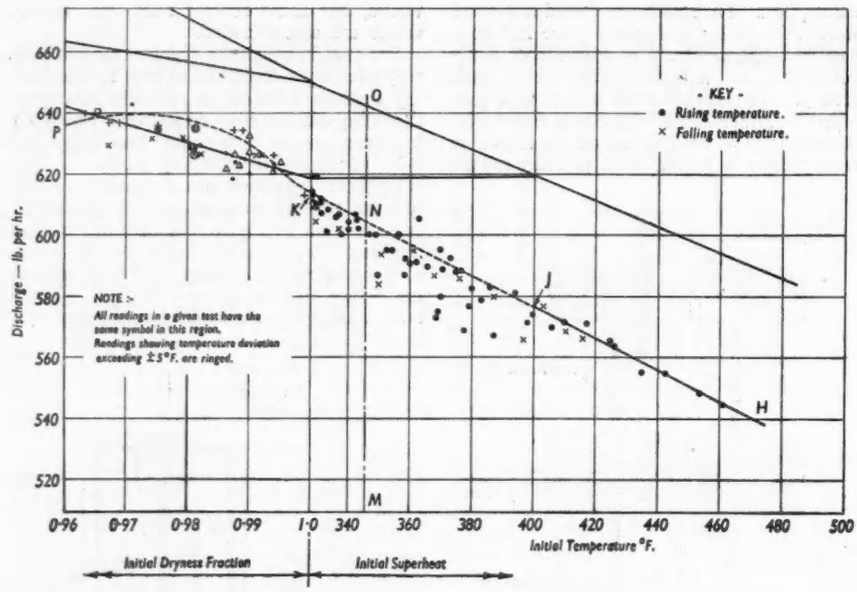


Fig. 9—Discharge valves nozzle No. 3, ¼in smooth search tube

that the end point Q of the supersaturated expansion falls well above the normal self-nucleation limit. Experiments were conducted with Nozzle No. 2 with both rough and smooth search tubes of diameters ¼in and $^{15}/_{32}$in, four tests in all. Experiments were also conducted with Nozzle No. 3 with the ¼in diameter rough and smooth search tubes. The flow curves are similar in form for all six cases, and only one pair need be shown, Figs. 9 and 10.

Considering Figs. 9 and 10, the following points may be observed :—

(*a*) The trend of the experimental points from H to K clearly shows that they define a line of the type *NML* (Fig. 1) corresponding to dry expansion rather than one of the type *NMJ* corresponding to equilibrium expansion.

(*b*) The statement (*a*) applies equally for both rough and smooth search tubes.

(*c*) There is no clearly defined reversionary trend of the type *RT* (Fig. 1) claimed by Mellanby and Kerr. The reversionary trend occurs only in the region of initial wetness.

(*d*) There is considerable random scatter in experimental points at qualities lower than that for which the exit steam is saturated.

A New Three-Phase Flow Theory

The present writer does not favour the analytical method devised by Mellanby and Kerr, and for the assessment of the present results the following theory is proposed which is a simple extension of the standard theory.

To provide a criterion for the ideal flow of partly reverted steam the entry fluid may be assumed divided into discrete streams in the manner shown in Fig. 11. If unit mass of entry steam of dryness fraction q is taken, we have at the controlling section of the nozzle :

(i) $(1-q)$ of original globules.

(ii) q of originally dry saturated steam which has sub-divided to give :

(*a*) $q\ (1-x)$, which has supersaturated, x being the fractional reversion.

(*b*) qx, which has expanded in equilibrium yielding q^1qx of dry saturated steam and $(1-q^1)qx$ of transit globules which have been precipitated during the passage through the nozzle.

If the entry steam is dry or superheated the subdivision is similar except that quantity (i) disappears.

It is assumed that each of the fractions (*a*) and (*b*) expand independently, bringing their respective contributions to the aggregate

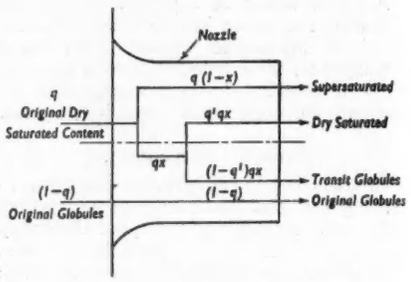


Fig. 11—Fluid streams

heat drop. The original and transit globules may each cool completely, incompletely or not at all, and thus add or detract from the aggregate heat drop.

Let H_E=nominal isentropic heat drop/unit mass from the equilibrium fraction, (*b*) above.

H_S=isentropic heat drop/unit mass from the supersaturated fraction, (*a*) above.

$\int Tdw$=defect in heat drop consequent upon failure of the transit globules to cool, dw being the precipitation in an elementary length of nozzle, and T the excess temperature at discharge of this precipitation.

Thus the effective heat drop from the equilibrium fraction is $qxH_E-\int Tdw$, while the supersaturated fraction contributes $q(1-x)H_S$ Suppose the common inlet temperature is T_I and the exit temperature of the combined vapour content for the degree of reversion prevailing is T_E. The original globules may be discharged at a temperature T_D, where $T_I>T_D>T_E$, their effective heat drop having been $(T_I-T_D)(1-q)$. Neglecting, as is usual, the small common entrance velocity, the energy conversion equation becomes, after adjustment,

$$V=223\cdot8\sqrt{\{qxH_E-\int Tdw+q(1-x)H_S+(1-q)(T_I-T_D)\}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where V is the exit or throat velocity assumed common to the entire mixture. For a justification that the liquid globules can be so treated, the reader is referred to reference [2]. The volume at the controlling section is the sum of the several volumes of the original globules, the reverted content and the supersaturated content, i.e.,

$$v=(1-q)v_W+qx[q^1v_S+(1-q^1)v_W]+q(1-x)v_{SS} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The mass discharge W for a controlling area of A is given by the standard expression

$$W=\frac{AV}{v} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

By equation (1) and (2) in (3)

$$W=\frac{A\,.\,223\cdot8\sqrt{\{qxH_E-\int Tdw+q(1-x)H_S+(1-q)(T_I-T_D)\}}}{(1-q)v_W+qx[q^1v_S+(1-q^1)v_W]+q(1-x)v_{SS}} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

This may be simplified, if desired, by rejection of the small terms in the denominator which cater for liquid volume.

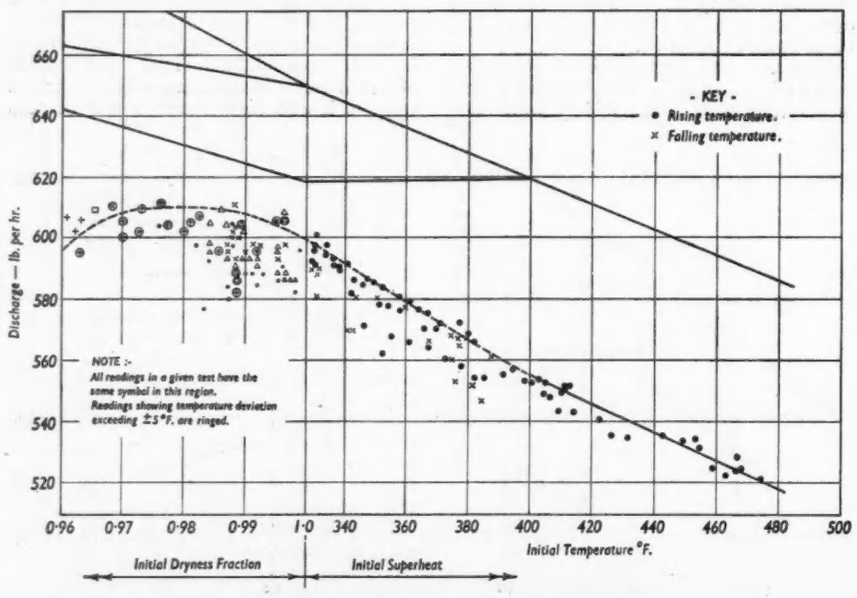

- KEY -
• Rising temperature.
× Falling temperature.
NOTE :-
All readings in a given test have the same symbol in this region.
Readings showing temperature deviation exceeding ±5°F. are ringed.
Discharge — lb. per hr.
Initial Temperature °F.
Initial Dryness Fraction
Initial Superheat

Fig. 10—Discharge valves nozzle No. 3, ¼in rough search tube

The ideal flow curves are obtained from (4) as follows :—

(*a*) *Equilibrium Flow.*—For the interval *MJ* (Fig. 1), where q and x are both unity,

$$W=\frac{A\,.\,223\cdot8\sqrt{H_E}}{q_1 v_{S1}} \quad . \quad . \quad . \quad (5)$$

where q_1 and v_{S1} are on the equilibrium parameters for the end point of the isentropic, and $\int Tdw=0$ assumes no transit globule loss.

For the interval *HJ*, where x is unity and no globule loss occurs

$$W=\frac{A\,.\,223\cdot8\sqrt{\{qH_E+(1-q)(T_I-T_E)\}}}{(1-q)v_W+qq^1v_S+q(1-q^1)v_W} \quad . \quad (6)$$

(*b*) *Supersaturated Flow.*—For the interval *ML*, where $q=1$ and $x=0$,

$$W=\frac{A\,.\,223\cdot8\sqrt{H_S}}{v_{SS}} \quad . \quad . \quad . \quad . \quad (7)$$

For the interval *LK* two possible viewpoints are considered. In the first case, if the original globules fail completely to cool, the factor $(1-q)(T_I-T_D)=0$, and

$$W=\frac{A\,.\,223\cdot8\sqrt{qH_S}}{(1-q)v_W+qv_{SS}} \quad . \quad . \quad . \quad . \quad (8)$$

If, on the other hand, the original droplets cool completely

$$W=\frac{A\,.\,223\cdot8\sqrt{\{qH_S+(1-q)(T_I-T_E)\}}}{(1-q)v_W+qv_{SS}} \quad . \quad (9)$$

Both cases are shown on Figs. 9 and 10, the upper curve corresponding to equation (9) and deemed to be the more realistic.

The steam temperature at any section may be shown to depend on the local fractional reversion x in the following way. Let T_{SS} be the steam temperature for complete supersaturation and T_R for complete equilibrium. Then, neglecting small effects such as retained globule heat, slightly differing specific heats, &c., the actual temperature T_E will lie between T_{SS} and T_R proportionally to the amount of reversion obtaining, i.e.

$$T_E=T_{SS}+(T_R-T_{SS})x \quad . \quad . \quad . \quad (10)$$

The expression (4) gives the ideal mass flow for isentropic expansion. The actual flow will be less than this by a factor C_D, the discharge coefficient applicable to the dry flow. It will be recalled that with partly reverted steam there are two factors depressing the discharge below the value applicable to isentropic totally supersaturated flow, namely, the effect of reversion and the dry flow friction. The former has been accommodated in equation (4) and C_D accommodates the latter. We have, therefore,

Actual discharge

$$W^1=\frac{C_D\,.\,A\,.\,223\cdot8\sqrt{\{qxH_E-\int Tdw+q(1-x)H_S+(1-q)(T_I-T_D)\}}}{(1-q)v_W+qx[q^1v_S+(1-q)v_W]+q[1-x]v_{SS}} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Evidence will be adduced later to suggest that reversion occurs upon the original globules in which case $\int Tdw=0$ and T_D will be at the exit temperature of the steam T_E, which is a function of the reversion as given in equation (10). Equation (11) may therefore be modified to

$$W^1=\frac{C_D\,.\,A\,.\,223\cdot8\sqrt{\{qxH_E+q(1-x)H_S+(1-q)[T_I-(T_{SS}+\{T_R-T_{SS}\}x)]\}}}{(1-q)v_W+qx[q^1v_S+(1-q^1)v_W]+q[1-x]v_{SS}} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Of the quantities in equation (12), W^1 and A can be measured, q can be obtained experimentally with a throttling or other calorimeter, and H_E, q^1, v_S and v_W can be obtained from the known properties of steam. H_S and v_{SS} for the supersaturated steam can be calculated from the equations applicable to superheated steam. If, therefore, C_D can be determined, the fractional reversion x is the only unknown and can be found by solving the resulting quadratic equation.

A suitable value for C_D can be found in a fairly satisfactory way as follows. Referring to Fig. 9, there is no duality of flow possible in the range H to J, and the scatter of the experimental values in this range, as defined by the standard deviation, gives an indication of the extent of normal experimental error combined with the limitations of the apparatus. Inspection of Fig. 9 suggests that for the range *JK* the higher experimental values are associated with zero reversion. Accordingly, *JK* may be drawn in such a way as to define the same standard deviation on the positive side as that of *HJ*. For any initial conditions M the value of C_D will be defined as $\frac{MN}{MO}$ and the value required for equation (12) is that prevailing at K. If the above procedure be allowed, it is possible to employ equation (12) to find the fractional reversion for any experimental flow value in the range for which reversion is a possibility.

For each nozzle and search tube combination a flow line corresponding to *KP* (Fig. 9) has been drawn in such a way as to preserve the value of positive standard deviation as described above. Owing to the considerable scatter of the experimental points in this region, the placing of this line is to some extent arbitrary. Using this line to define W^1 in equation (12) it is possible to calculate the trend of minimum reversion for each of the six cases over the whole range of initial wetness and thus to obtain the experimental reversion curves which are

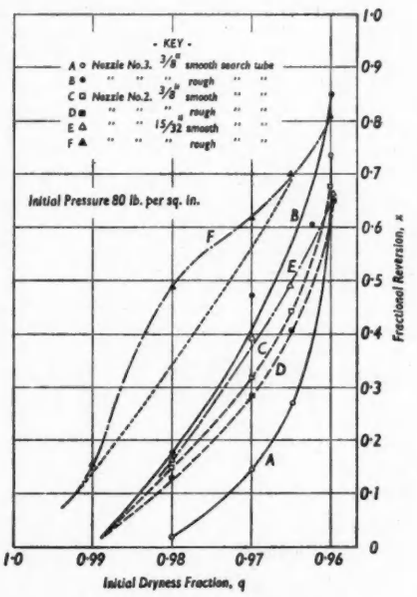
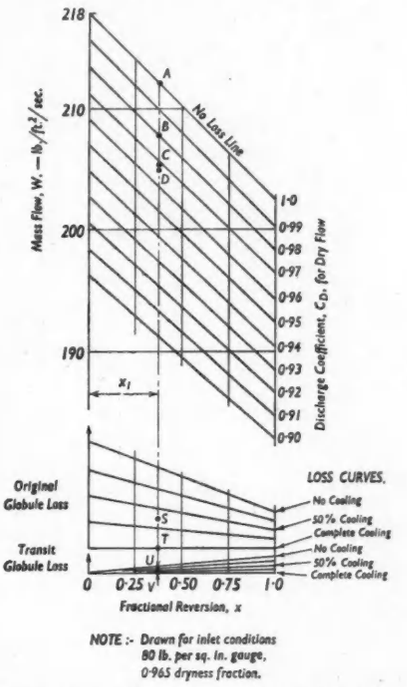


Fig. 12—Experimental reversion curves

shown in Fig. 12. Comparison of these curves with the corresponding curves due to Mellanby and Kerr (Fig. 3) shows a general similarity in shape and trend, but a displacement laterally along the dryness fraction axis.

A comparison of the respective performances of the several nozzle and search tube combinations for specified inlet conditions may also be presented in the following way.

If an analysis is made of the form of equation (4) it may be shown that the discharge loss due to failure of the transit globules to cool is substantially independent of the behaviour of the original globules, and that the flow is nearly linear with the reversion. It may also be shown that for a constant value of original globule cooling the defect in flow is again approximately linear with the reversion and is independent of the transit globule behaviour. These facts make possible the construction of a simple and neat diagram to cover all loss effects occurring before the controlling section, and such a diagram is shown in Fig. 13. It will be referred to as a



NOTE :- Drawn for inlet conditions 80 lb. per sq. in. gauge, 0·965 dryness fraction.

Fig. 13—The general flow diagram for partly reverted steam

"general flow diagram." The respective loss curves for original globules and transit globules are shown at the bottom of the diagram. The lines above are lines of mass flow, and all are on a base of fractional reversion. The ideal flow line is that for zero friction loss, whilst the lower lines are for values of dry discharge coefficient $C_D=0\cdot99$, $0\cdot98$, &c. As an example of the use of the diagram, consider that a nozzle is operating with the appropriate inlet conditions. Let the degree of reversion be x_1. In the absence of any loss the operating point is at A. If the pure friction effects cause a loss of, say, 2 per cent, the point falls to B. If incomplete cooling of the original globules occurs the appropriate loss for this reversion, say, *ST*, is deducted and the point C obtained. A similar deduction for transit globules loss *UV* leads to the point D, which is the operating point for the conditions prevailing.

Fig. 14 shows a general flow diagram for the same original conditions as Fig. 13, on which the flow points applicable to a dryness fraction of $0\cdot965$ have been exhibited for each nozzle and search tube combination. In the absence of globule loss each point is readily defined by the intersection of the appfopriate flow and value of C_D.

Droplet Growth Factor

In the probable absence of self-nucleation it is not unreasonable to suggest that transit precipitation may occur upon sub-divided original globules. If, therefore, the case be considered in which the steam is wet at entry, then for an initial dryness fraction of q there is a mass $1-q$ of liquid to present surface for growth. For a fractional reversion

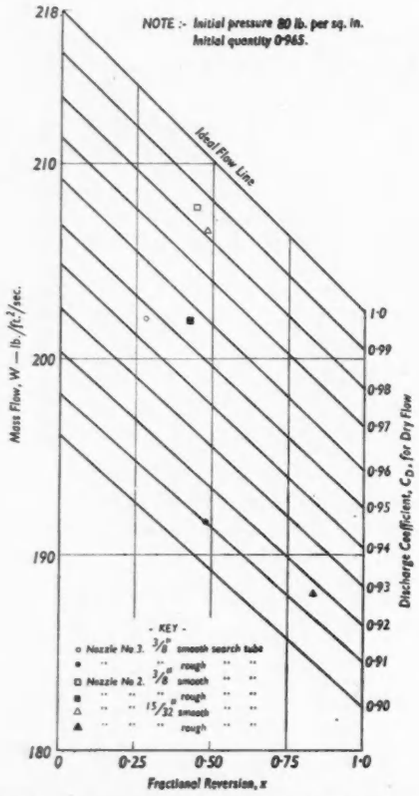

NOTE :- Initial pressure 80 lb. per sq. in.
Initial quantity 0·965.
Ideal Flow Line
Mass Flow, W — lb./ft.²/sec.
Discharge Coefficient, C_D, for Dry Flow
Fractional Reversion, x
- KEY -
Nozzle No 3. 3/8" smooth search tube
" " " rough " "
Nozzle No 2. 3/8" smooth " "
" " " rough " "
15/32" smooth " "
" " " rough " "

Fig. 14—Experimental flow values shown on a general flow diagram

of x the precipitated transit liquid will be $(1-q^1)qx$. If this liquid is condensed upon the original liquid, then for any degree of atomisation an average exit growth factor may be defined thus :

$$\text{Growth Factor} = \frac{(1-q)+(1-q^1)qx}{1-q} \quad . \quad . \quad . \quad (13)$$

which, for zero reversion, is unity and for full reversion, when $x=1$, becomes

$$\frac{1-qq^1}{1-q} \quad . \quad . \quad . \quad . \quad (14)$$

For the present experiments, in which the initial pressure is 80 lb per square inch and $q^1=0{\cdot}9645$, values of growth factor may be calculated from equation (13) for various values of q. These have been drawn as parameters on Fig. 15, which has axes of q and x. Comparison of the curves, Fig. 12, with those of Fig. 15 reveals a marked similarity and supports the suggestion that liquid precipitated during transit is in fact

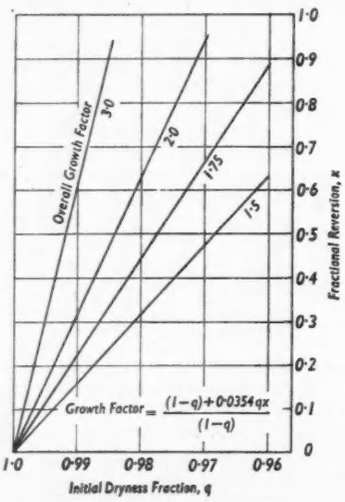


Fig. 15—Growth factor curves

condensing upon the liquid already present. The issue can, however, be tested by an appeal to the physics of droplet growth, in order to ascertain if such growth would give a growth factor in the range, say, 1·75 to 2, which makes comparison valid.

Physics of Droplet Growth

As an example, consider Nozzle No. 3 with a $\frac{3}{8}$in diameter search tube. It may be established that within the short radiused entry the steam velocity rises abruptly from a negligible value to about 340ft per second. This will cause initial "atomisation" of the original globules, and reference to a globule fracture chart previously published by the writer[3] shows that the size order after fracture will be 5×10^{-7}ft to 5×10^{-6}ft radius.

For droplet growth in a steam atmosphere, Oswatitsch[4] gives the following equation :

$$\frac{dm}{dt}=\frac{8\pi K(T_R-T_{SS})}{3L} \quad . \quad . \quad . \quad (15)$$

Since

$m=4\pi r^3\rho_w/3$, and since $\frac{dr}{dl}=\frac{dr}{dt}\cdot\frac{dt}{dl}$, where $\frac{dt}{dl}=\frac{1}{V}$

equation (15) may be written in terms of the nozzle length l,

$$\frac{dr}{dl}=\frac{K(T_R-T_{SS})}{rL\rho_w V} \quad . \quad . \quad . \quad (16)$$

The thermal conductivity of supersaturated steam may be taken, in default of experimental knowledge, as

$$K=\mu C_v \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

For supersaturated steam C_v is unknown, but for the limited temperature range involved it may be calculated with sufficient accuracy by extrapolating curves of C_p and R. The viscosity μ may be taken from Sigwart's expression for dry steam,

$$\mu=\{0{\cdot}143[T_R-460]+56\}\times10^{-7}\ \text{lb/ft-sec} \quad . \quad . \quad . \quad . \quad . \quad (18)$$

which is insensitive to temperature.

The velocity distribution for this nozzle and search tube combination may be calculated from elementary theory and is closely represented by

$$V=144l^2+340\text{ft/sec} \quad . \quad . \quad (19)$$

For total supersaturation the distribution of undercooling with length may be calculated and may be shown to conform closely to

$$(T_R-T_{SS})=8l+5\ .\ \exp.\ (4{\cdot}88l-9{\cdot}76)\ \text{deg. Fah.} \quad . \quad . \quad . \quad . \quad . \quad (20)$$

where l is in inches in both equations (19) and (20).

By equations (19) and (20) in (16) and after supplying the physical quantities K, L and ρ_w one obtains

$$\frac{dr}{dl}=\frac{8{\cdot}2\times10^{-11}}{r}[8l+5\ \exp.\ (4{\cdot}88l-9{\cdot}76)][144l^2+340]^{-1} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

which has the solution

$$r^2=1{\cdot}64\times10^{-10}\int[8l+5\ \exp.\ (4{\cdot}88l-9{\cdot}76)][144l^2+340]^{-1}dl+A\ \text{constant} \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The value of the constant is obtained from the known conditions that $r=5\times10^{-6}$ft when $l=0{\cdot}25$in. The value of the integral may be obtained by plotting and hence the growth of a globule may be exhibited on a basis of length. A "calculated" growth factor may thus be obtained for comparison with equation (13).

Calculations have been made for Nozzle No. 3 and Nozzle No. 2, each with the $\frac{3}{8}$in search tube, and the respective rates of growth and calculated growth factors are shown on Fig. 16. For the latter combination, the original radius after fracture is found to be

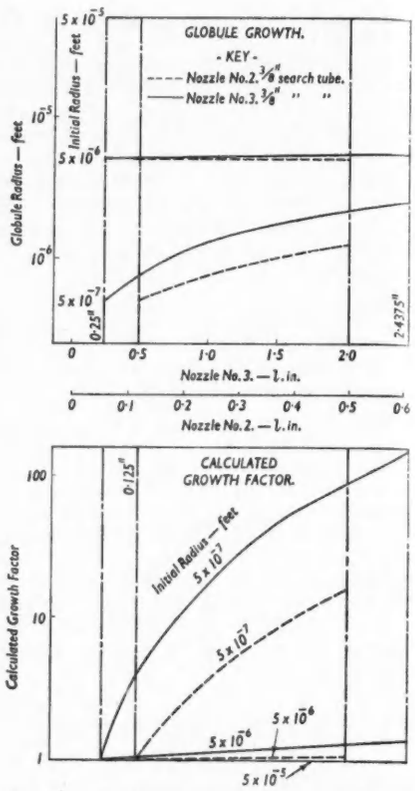

GLOBULE GROWTH.
- KEY -
Nozzle No.2. 3/8" search tube.
Nozzle No.3. 3/8" " "
Globule Radius — feet
Initial Radius — feet
Nozzle No. 3. — l. in.
Nozzle No. 2. — l. in.
CALCULATED GROWTH FACTOR.
Calculated Growth Factor
Initial Radius — feet

Fig. 16—Rates of growth and calculated growth factors

about 5×10^{-7}ft to 5×10^{-6}ft as before.

It is immediately apparent from Fig. 16 that the original size of the globule is of paramount importance in determining the growth factor, but if the original "atomised" sizes are allowed, then the calculated growth factors show good correspondence with the factors required and support the suggestion that transit precipitation takes place on the original globules. Earlier in this article the question of the cooling of transit and original globules arose. It is now seen that the original and precipitated liquid must have a common temperature, and since failure of the composite globule to cool would render it unsuitable as a centre for further condensation it is reasonable to suggest that it maintains its temperature approximately at the same value as the surrounding fluid. Corrections for failure to cool thus become unnecessary in the present case.

It should be noticed that the theory leading to equation (22) has not taken any cognizance of the relief of supersaturation as reversion proceeds and therefore the calculated values of growth and growth factor are rather too large. This relief of supersaturation can be accommodated by modifying the differential equation (16), but at the expense of considerable complication, and is not necessary for the present inquiry which is only concerned with checking the order of the growth factor.

Promotion of Reversion by Friction

An inspection of Fig. 14 shows that, other things being equal, the fractional reversion is greater when rough search tubes are employed than when the tubes are smooth, and this suggests that friction on the boundary encourages reversion. There is much evidence to support this, and the work of Kerr, Scott and Sorour[5] may be quoted as one example. These workers found that reversion could be promoted by a plane shock in a Laval nozzle divergence at values of supersaturation ratio less than the critical value for self-nucleation. The writer is engaged on research into the

mechanism of this type of reversion and it is hoped to treat the subject in a later paper.

Influence of Small Foreign Nuclei

It has been pointed out above that experimental points in the region *J-P* (Fig. 9) show considerable scatter. It is thought that this scatter arises from uncontrolled and irregular condensation upon stray nuclei entering the boiler via the feed water, e.g. dirt and finely divided carbon, or produced within the system, e.g. metallic and oxide particles. It is not possible, unfortunately, to eliminate these foreign elements and they make the analysis of experimental work much more difficult.

Conclusions

The above work indicates conclusively that for the conditions of the experiments some supersaturation occurs in expanding steam of low initial quality, even if it is wet at entrance to the nozzle. It is capable of persisting to the controlling section and therefore of influencing the mass discharge. Supersaturation has, in fact, been shown to take place even in "slow" expansions, hitherto generally considered to be immune. There is strong evidence to suggest that such condensation as does occur in transit occurs by the deposition of new liquid upon liquid precipitated earlier, and that self-nucleation is absent. Evidence also suggests that reversion is encouraged by severe boundary friction.

The practical question then arises as to what extent supersaturation may be expected to occur in low pressure turbines. It is not possible to give a general answer covering each individual case, but the following can be affirmed with confidence. Considerable supersaturation will certainly occur in the expansion element in which the state point locus crosses the nominal saturation limit and here, blades or nozzles should be designed accordingly. Some supersaturation may be expected at any stage thereafter. Its extent will be greater the greater the pressure drop across the element and less in proportion to the liquid present to form growth centres. Careful drainage will tend to encourage supersaturation. Some reversion by shock will occur at the blade entry when the speed is off-design. Any agencies which promote fine "atomisation" of undrained droplets (sudden velocity changes, impact with metal surfaces, &c.) will tend to suppress supersaturation because droplet growth will be more vigorous.

The use of the heat-entropy chart for l.p. end design must be regarded as somewhat in error. This error is probably insignificant for large turbines in which the "wet" region expansion is spread over many stages, but it will assume increasing importance as the number of stages is reduced.

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Radial Temperature Distribution in an Annular Coolant Passage

By HENRY BARROW*

This article deals with the fundamental problem of radial temperature distribution in a fluid flowing turbulently in an annulus with a heated core. While its applications are limited, it is intended as a contribution towards the solution of the general heat transfer problem in annular coolant passages.

THERE are many practical cases in heat transfer engineering in which an annular flow passage might be employed. Perhaps the most recent application is the primary coolant passage of a nuclear heterogeneous reactor, which in its simplest mechanical form consists of cylindrical rods of the fuel element located centrally in circular ducts in the moderator. The coolant fluid, which may be either of a gaseous or a liquid form, removes the heat produced by nuclear fission in the fuel cores by the mechanism of forced convection, and this heat is then transferred to a secondary coolant through the agency of a heat exchanger. The design of this heat exchanger depends to some extent on the nature of the fluids used in the circuits, and here, too, the annulus section is a possible form of flow passage.

Of the non-circular sections, the annulus is perhaps the simplest one with which to deal, but, despite extensive experimental investigations on both fluid flow and heat transfer, the annulus problem has not been completely solved. Because of the difficulties encountered in experimental work of this nature, in particular that of simulating true annular flow, the experimental data and the derived correlations must be considered with caution. Eccentricity of the core in the enclosing pipe has a marked effect on heat transfer, and this is probably the main reason for the inconsistency in results.

Earlier investigators in this field of work used only a limited range of fluids, and heat fluxes which are small by comparison with present-day values, so that their equations are not likely to apply with any accuracy to the more recent applications. For large heat fluxes, liquid metals are particularly suitable as the primary coolant because of their high heat transfer coefficients and high heat capacities. However, these fluids require special consideration not only because of mechanical difficulties generally, but also because heat conduction is of importance in the forced convection process.

While heat may be transferred at both boundaries of the cross section, as in the case of a heat exchanger having multiple concentric annuli as flow passages, the simplest practical case of asymmetric heating is when heat exchange takes place at the inner boundary only. An entirely theoretical solution of this heat transfer problem is difficult because the velocity and temperature profiles as shown in Fig. 1 are dissimilar, and the direct use of the analogy between fluid friction and heat transfer which is usually applied in pipe flow is not possible. Furthermore, many of the potential coolant fluids require special considerations which make a general treatment lengthy, if not impossible. If, however, theoretical methods are to be employed, a knowledge of velocity distribution is essential in the heat transfer problem. There are two possible methods of describing the turbulent velocity distribution in an annular passage; they are:

(1) A "power law," as is used in open pipe flow, and (2) a generalised velocity distribution or universal velocity profile which is independent of the Reynolds number.

A thorough investigation of fluid friction and velocity distribution has been made by Rothfus, Monrad and Senecal (1950), and by considering an equivalent open pipe they modified the co-ordinates of the universal velocity profile diagram to correlate their experimental velocity data. They showed also that an equation of the same form as that employed for smooth circular tubes could be used to correlate their friction results. The reader is referred to their paper for a detailed explanation of the method.

On the other hand, radial temperature distribution measurement, from which heat transfer can be determined, seems to have been neglected and as far as the author is aware little is recorded in the published literature. Symmetry of both velocity and temperature profiles across the fluid section is the criterion of correct flow in a concentric annulus for both symmetric and asymmetric heating.

In the most general case, the nature of the boundary wall surfaces is different. For example, the heat transfer area may be increased artificially by the use of fins or projections, but the flow in such a passage cannot be classed as annular.

In a preliminary analytical investigation of

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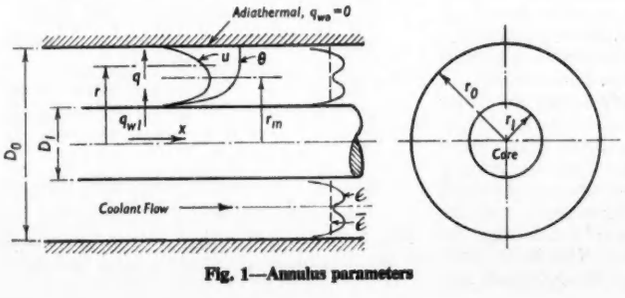


Fig. 1—Annulus parameters

Nomenclature.

c—Specific heat at constant pressure.
D, $D_e = D_0 - D_i$—Diameter, "equivalent" diameter.
ϵ, $\bar{\epsilon}$—Eddy diffusivity, average eddy diffusivity.
$h = q_{wi}/(\theta_{wi} - \theta_b)$—Heat transfer coefficient.
k—Thermal conductivity.
q—Heat flux per unit area.
r—Radius.
u, $\bar{u}$—Velocity, average velocity.
W—Mass flow.
x—Axial distance.
θ—Temperature.
μ—Absolute viscosity.
ρ—Fluid density.
$\nu = \mu/\rho$—Kinematic viscosity.
τ—Shear stress.
$= 2\tau_o/\rho\bar{u}^2$—Friction factor.
B, E—Constants.

Suffices.

b—Bulk.
H—Heat.
i—Inner.
l—Laminar sub-layer/turbulent region interface.
m—Maximum.
M—Momentum.
o—Outer.
w—Wall.

Additional Notation.

$A = \dfrac{r_i}{r_0^2 - r_i^2}$

$\alpha = \dfrac{r_0}{r_i}$, radius ratio.

$\beta = \dfrac{2\alpha^2 \log_e \alpha - \alpha^2 - 1}{2\alpha(\alpha - 1)\log_e \alpha}$

$\gamma = \dfrac{\alpha(\alpha^2 - 1 - 2\log_e \alpha)}{2\alpha^2 \log_e \alpha - \alpha^2 + 1}$

} Annular characteristics.

temperature distribution in an annulus it is convenient to consider a smooth perimeter with heat transfer at the core wall only. An additional simplification is to assume that the heat flux is constant lengthwise, since it is not to be expected that the heat flux variation has any marked effect on the terminal temperature profile except for certain fluids. The heat transfer coefficient is in most cases constant in the flow direction, for if the length equivalent ratio for the passage is large the flow is fully developed, both hydrodynamically and thermally, for the major part of its length.

With these simplifying assumptions the theoretical approach to the annular heat transfer problem is then similar to that employed for the circular pipe.

Theory

The case to be considered is that of fully developed turbulent flow in a smooth-walled annular space with uniform heat flux at the core wall, the outer wall being maintained adiathermal. The boundary conditions are symmetrical about the core axis. Using the concept of eddy diffusivity which measures the contribution of the turbulent mixing to shear stress and heat transfer, the local heat flux and local shear stress are given by the well-known equations :

$$\frac{q}{c\rho}=-\left(\frac{k}{c\rho}+\varepsilon_H\right)\frac{d\theta}{dr} \quad . \quad . \quad . \quad (1)$$

and

$$\frac{\tau}{\rho}=(\nu+\varepsilon_M)\frac{du}{dr} \quad . \quad . \quad . \quad . \quad (2)$$

where ε_H and ε_M are the eddy diffusivities of heat and momentum respectively. The degree of turbulence, and hence the eddy diffusivity, varies across the flow cross section and generally the local values of ε_H and ε_M differ. While values varying from 1 to 1·6 have been suggested for the ratio $\varepsilon_H/\varepsilon_M$, in the simplest analysis ε_H and ε_M are assumed equal, and in the following, $\varepsilon_H=\varepsilon_M=\varepsilon$.

The temperature profile, which is to be determined, may be considered to be terminal when

$$\frac{\partial}{\partial x}\left(\frac{\theta_{w1}-\theta}{\theta_{w1}-\theta_b}\right)=0 \quad . \quad . \quad . \quad (3)\dagger$$

With the conditions of uniform heat flux q_{w1}, uniform heat transfer coefficient (defined by $h=q_{w1}/(\theta_{w1}-\theta_b)$), and constant fluid properties, $\partial\theta_b/\partial x$ and $\partial\theta_{w1}/\partial x$ are constant and equal, so that equation (3) gives

$$\frac{\partial\theta}{\partial x}=\frac{\partial\theta_{w1}}{\partial x}\left(=\frac{\partial\theta_b}{\partial x}\right)=\text{constant.}$$

This indicates that the local axial temperature gradient $\partial\theta/\partial x$ is independent of the radial position in the fluid section.

From Fig. 1 :

$$q_{w1}\,.\,2\pi r_1=Wc\frac{\partial\theta}{\partial x}$$

and

$$q\,.\,2\pi r=2\pi\rho c\frac{\partial\theta}{\partial x}\int_r^{r_0} ur\,.\,dr$$

are heat balance equations.

Eliminating $\partial\theta/\partial x$ which is constant, the local heat flux q of equation (1) is given by

$$q=q_{w1}\,.\,\frac{2\pi r_1\rho}{rW}\int_r^{r_0} ur\,.\,dr \quad . \quad . \quad . \quad (4)$$

In the turbulent region, the velocity may be assumed constant and equal to the average velocity, $\bar{u}$, and since the mass flow

$$W=\bar{u}\rho\pi(r_0^2-r_1^2)$$

equation (4) simplifies to

$$q=q_{w1}\frac{r_1}{r}\left(\frac{r_0^2-r^2}{r_0^2-r_1^2}\right).$$

† Seban and Shimazaki, 1951.

For fully developed flow in an annulus, the shear stress distribution can be written as

$$\tau=\tau_{w1}\left(\frac{r_1}{r}\right)\left|\left(\frac{r_m^2-r^2}{r_m^2-r_1^2}\right)\right| \quad . \quad . \quad . \quad (5)$$

where r_m is the radius of maximum velocity.

Rothfus, Monrad and Senecal (1950) in their experiments on velocity distribution in smooth concentric annuli observed that the radius of maximum velocity in turbulent flow agreed with that predicted by Lamb's theoretical equation (1924) for laminar flow, viz.

$$r_m=\sqrt{\frac{r_0^2-r_1^2}{2\log_e(r_0/r_1)}},$$

which is less than $\left(\frac{r_0+r_1}{2}\right)$, the mean radius.

Equation (5) is valid for both laminar and turbulent flow and the inner wall friction τ_{w1} is greater than the outer wall friction τ_{w0}. Substitution of the expressions for the local heat flux q and local shear stress τ in the equations (1) and (2) give the basic equations for heat transfer and fluid flow in an annulus for the conditions cited. Then

$$\frac{q_{w1}}{c\rho}\left(\frac{r_1}{r}\right)\left(\frac{r_0^2-r^2}{r_0^2-r_1^2}\right)=-\left(\frac{k}{c\rho}+\varepsilon\right)\frac{d\theta}{dr} \quad . \quad . \quad (6)$$

and

$$\frac{\tau_{w1}}{\rho}\left(\frac{r_1}{r}\right)\left|\left(\frac{r_m^2-r^2}{r_m^2-r_1^2}\right)\right|=(\nu+\varepsilon)\frac{du}{dr} \quad . \quad . \quad (7)$$

For an investigation of the heat transfer problem it is convenient to divide the annular fluid section into two regions : (1) laminar sub-layers adjacent the inner and outer wall boundaries in which heat is transferred by conduction only, and (2) a turbulent fluid core in which turbulent mixing predominates in the heat transfer process, a condition fulfilled when the Prandtl number of the fluid is greater than about 0·6. Very little heat reaches the outer laminar sub-layer and consequently the temperature gradient there is very small. In this treatment, the transition layers, in which conduction and eddy heat transfer are both effective, are omitted.

Equations (6) and (7) can be solved to determine the temperature drop in the laminar sub-layer next to the heated boundary if : (1) the local shear stress τ and local heat flux q are assumed constant and equal to the wall values τ_{w1} and q_{w1} respectively. (This is a reasonable assumption when the laminar layer is thin.) (2) the eddy diffusivity $\varepsilon=0$, and (3) the velocity at the laminar sub-layer-turbulent core interface is known.

Equations (6) and (7) are then written in the simple forms :

$$q_{w1}=k\left(\frac{\theta_{w1}-\theta_i}{r_i-r_1}\right)$$

and

$$\tau_{w1}=\frac{\mu u_i}{(r_i-r_1)}.$$

Eliminating the sub-layer thickness (r_i-r_1), the temperature drop $(\theta_{w1}-\theta_i)$ is given by

$$\theta_{w1}-\theta_i=\frac{q_{w1}\,.\,\mu\,.\,u_i}{k\tau_{w1}} \quad . \quad . \quad . \quad (8)$$

In the turbulent region the molecular terms $k/c\rho$ and ν of the general equations (6) and (7) are negligibly small, compared with the molar term ε for the case under consideration, and can therefore be omitted when determining the temperature drop there. For a circular fluid section—that is, the case of a round pipe—the eddy diffusivity ε may be determined from equation (2) for use in equation (1) because the shear stress τ is a linear function of the radius r and the velocity distribution is known. If the heat flux q is assumed to vary in the same manner as the shear stress τ, equation (1) can then be solved for the temperature. This is the usual treatment for the circular fluid section and is dealt with thoroughly in the heat transfer literature. The basic equations (6) and (7) for the annular flow cannot be solved simultaneously in this way because of the complexity of the shear stress and heat flux distributions. Furthermore, the complicated equations correlating velocity distribution across the annulus aggravate this difficulty.

The eddy diffusivity, which must be known for the solution of the heat transfer equation (6) is dependent on the wall distance and the Reynolds number and varies across the annular section as shown diagrammatically in Fig. 1. While the curve is not symmetrical about the radius of maximum velocity, it is similar in shape to that obtained for the open pipe. This variation has been verified by experiments carried out by the author. For air flowing through an annulus of radius ratio 2¼ the velocity gradients du/dr at various radii were determined from the velocity profiles by a semigraphical method and equation (7) (with $\nu=0$) was used to evaluate ε. Wall friction was determined from pressure drop measurements in the usual way. In spite of the inaccuracies inherent in the method of determining the slope du/dr, reasonably fair curves of ε versus r were obtained.

The solution of equation (6), which requires a knowledge of the eddy diffusivity ε, is simplified if ε is assumed constant across the turbulent region and equal to the mean value. This is not unreasonable. For pipe flow, Murphree (1932) assumed that the eddy currents had a constant value in the main body of the fluid, and his result satisfactorily correlated the heat transfer data of other experimenters. From fluid flow considerations, ε should depend on the eddy size and the eddy velocity, the latter being conveniently measured by the root mean square of the instantaneous velocity deviations from the time average velocity. The mean eddy size depends on the size of the flow section and the mean eddy velocity depends on the mean flow velocity. From these considerations the average eddy diffusivity $\bar{\varepsilon}$ must vary with $(D_0-D_1)\bar{u}$ and therefore the ratio $\bar{\varepsilon}/\nu$ must vary with the Reynolds number Re defined by the equation

$$Re=\frac{(D_0-D_1)\bar{u}}{\nu}$$

where the equivalent diameter (D_0-D_1) $=(4\times$ flow area/wetted perimeter). It is to be expected that the equations connecting $\bar{\varepsilon}/\nu$ and Re will be of the form

$$\frac{\bar{\varepsilon}}{\nu}=B(Re)^E,$$

where B and E are constants, which can be determined experimentally. Fig. 2 shows

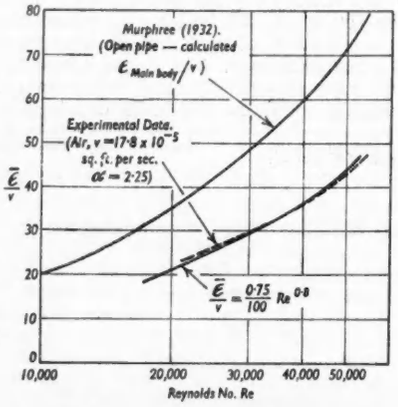


Fig. 2—Variation of average eddy diffusivity/kinematic viscosity ratio, $\frac{\bar{\varepsilon}}{\nu}$, with Reynolds' No. Re.

the mean of the author's experimental values of $\bar{\varepsilon}/\nu$ and the correlating equation

$$\frac{\bar{\varepsilon}}{\nu}=\frac{0{\cdot}75}{100}(Re)^{0{\cdot}9},$$

which is to be used in equation (6).

As indicated in the figure, Murphree's calculated results for the ratio of the main stream eddy diffusivity to the kinematic viscosity for the open pipe are approximately twice the values for the annulus at the same Reynolds number. From the previous considerations of the eddy diffusivity, this is what might be expected. Comparing an open pipe with an annulus having an "equivalent" diameter (D_0-D_1) numerically equal to the pipe diameter, at the same mean velocity, the Reynolds numbers will be the same in both cases. For the annulus, however, half the equivalent diameter (that is, the annular spacing or gap) is the dimension on which the mean eddy size depends. Therefore, if an equation of the form

$$\frac{\bar{\varepsilon}}{\nu}=B(Re)^E$$

applies to both the pipe and to the annulus, and if the exponent E is near unity, which appears to be the case, $\left(\frac{\bar{\varepsilon}}{\nu}\right)$ for the annulus will be approximately one-half that for the pipe at the same Reynolds number.

The temperature distribution in the turbulent region can now be determined by writing equation (6) as

$$\frac{q_{w1}}{c\rho}\left(\frac{r_1}{r}\right)\left(\frac{r_0^2-r^2}{r_0^2-r_1^2}\right)=-\frac{0{\cdot}75}{100}Re^{0{\cdot}9}\nu\frac{d\theta}{dr}$$

$k/c\rho$ being neglected. The use of equation (7) has now been avoided.

Separating the variables, and integrating

$$(\theta_1-\theta)=\frac{q_{w1}}{\nu c\rho}\cdot\frac{100A}{0{\cdot}75Re^{0{\cdot}9}}\left(r_0^2\log_e\frac{r}{r_1}-\frac{r^2}{2}+\frac{r_1^2}{2}\right) \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where

$$A=\left(\frac{r_1}{r_0^2-r_1^2}\right).$$

Adding equations (8) and (9), the total temperature drop

$$(\theta_{w1}-\theta)=\frac{q_{w1}\mu u_1}{k\tau_{w1}}+\frac{q_{w1}100A}{\nu c\rho 0{\cdot}75Re^{0{\cdot}9}}\left(r_0^2\log_e\frac{r}{r_1}-\frac{r^2}{2}+\frac{r_1^2}{2}\right).$$

Similarly, the temperature difference between the core and outer wall is

$$\theta_{w1}-\theta_{w0}=\frac{q_{w1}\mu u_1}{k\tau_{w1}}+\frac{q_{w1}100A}{\nu c\rho 0{\cdot}75Re^{0{\cdot}9}}\left(r_0^2\log_e\frac{r_0}{r_1}-\frac{r_0^2}{2}+\frac{r_1^2}{2}\right).$$

The dimensionless temperature ratio is therefore :

$$\frac{\theta_{w1}-\theta}{\theta_{w1}-\theta_{w0}}=\frac{1+\dfrac{100A\tau_{w1}}{Pr\,.\,\nu\rho 0{\cdot}75Re^{0{\cdot}9}u_1}\left(r_0^2\log_e\dfrac{r}{r_1}-\dfrac{r^2}{2}+\dfrac{r_1^2}{2}\right)}{1+\dfrac{100A\tau_{w1}}{Pr\,.\,\nu\rho 0{\cdot}75Re^{0{\cdot}9}u_1}\left(r_0^2\log_e\dfrac{r_0}{r_1}-\dfrac{r_0^2}{2}+\dfrac{r_1^2}{2}\right)}.$$

For flow in an annulus, the following relationships hold. First :

$$\tau_{w1}=\gamma\tau_{w0}$$

where

$$\gamma=\frac{r_0\left(r_m^2-r_1^2\right)}{r_1\left(r_0^2-r_m^2\right)}=\alpha\left(\frac{\alpha^2-1-2\log_e\alpha}{2\alpha^2\log_e\alpha-\alpha^2+1}\right)$$

from equation (5), and according to Rothfus, Monrad and Senecal (1950)

$$f_0=0{\cdot}079(Re\beta)^{-\frac{1}{4}}$$

with

$$f_0=2\tau_{w0}/\rho\bar{u}^2$$

and

$$\beta=\frac{2\alpha^2\log_e\alpha-\alpha^2-1}{2\alpha(\alpha-1)\log_e\alpha}$$

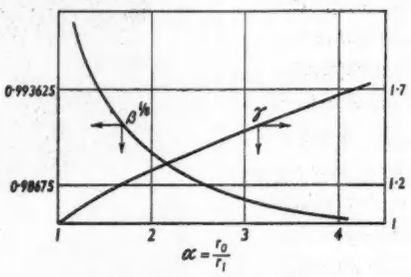
Furthermore, at the sub-layer turbulent region interface,

$$u_1\Big/\sqrt{\frac{\tau_{w0}}{\rho}}=11{\cdot}7.$$

Substituting these expressions gives the final temperature ratio

$$\frac{\theta_{w1}-\theta}{\theta_{w1}-\theta_{w0}}=\frac{1+2{\cdot}26\dfrac{Re^{0{\cdot}875}}{Pr}\cdot\left(\dfrac{A}{D_e}\right)\left(\dfrac{\gamma}{\beta^{\frac{1}{4}}}\right)\left(r_0^2\log_e\dfrac{r}{r_1}-\dfrac{r^2}{2}+\dfrac{r_1^2}{2}\right)}{1+2{\cdot}26\dfrac{Re^{0{\cdot}875}}{Pr}\cdot\left(\dfrac{A}{D_e}\right)\left(\dfrac{\gamma}{\beta^{\frac{1}{4}}}\right)\left(r_0^2\log_e\dfrac{r_0}{r_1}-\dfrac{r_0^2}{2}+\dfrac{r_1^2}{2}\right)} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

For practical values of the radius ratio α, $\beta^{\frac{1}{4}}$ is sufficiently near 1 to be omitted, while values of the annular characteristic γ are readily obtained from Fig. 3. The laminar



(Adapted from Barrow, 1955)

Fig. 3—Annular characteristics

sub-layer thickness (r_1-r_1) is small and decreases with increasing Reynolds number, and as greater accuracy is not warranted r_1 may be substituted for r_1 in the calculation of the temperature ratio. A comparison between equation (10) and the author's experimental results Barrow (1955) for air flowing in an annulus at near atmospheric pressure is made in Fig. 4.

Conclusions

Because of the simplifying assumptions the derived equation can only be considered

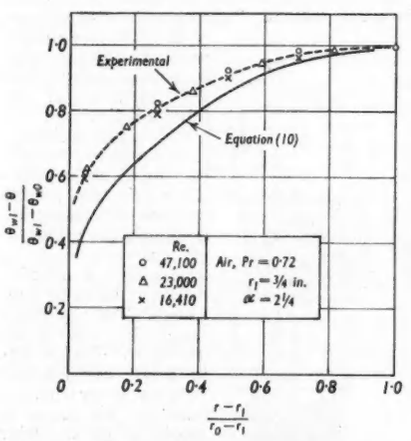


Fig. 4—Temperature profiles

reasonably satisfactory for fluids with a Prandtl number greater than about 0·6. Since fluid properties have been considered constant, the smaller the heat flux the more accurate is the equation likely to be. The temperature effect on fluid properties and hence heat transfer is significant even in the lower heat transfer range, while pressure effect is negligible on all the properties except the density. Constancy of heat transfer coefficient between the core and coolant implies very long flow passages. Perhaps the most questionable assumption made is that of constant heat flux, which is used for the simplification of the heat balance equations. It is not expected, however, to limit the use of the result for other flux distributions.

There is only fair agreement between the experimental and theoretical temperature profiles shown in Fig. 4, but in view of the nature of the problem, the result is encouraging. Better agreement would have been obtained if the constant value of the eddy diffusivity had been assumed equal to the maximum value instead of the average one. The constant appearing in the final expression would then have been smaller. There is, however, a basic weakness in equation (10). With increasing Reynolds number Re, the temperature ratio for any given fluid decreases and this is contrary to reality. The experimental profiles show what should be expected. It is evident that the result is sensitive to the choice of the exponent E in the equation correlating the average eddy diffusivity-kinematic viscosity ratio, with the Reynolds number, viz. $\bar{\varepsilon}/\nu=B(Re)^E$. The experimental curve of Fig. 2 is the mean of only four values, so that a more extensive investigation of eddy diffusivity in an annulus is required before the correct exponent can be determined.

The effect of variation in the Prandtl number is as expected, the temperature ratio increasing, that is the profile becoming more full, as the Prandtl number increases. Fig. 5

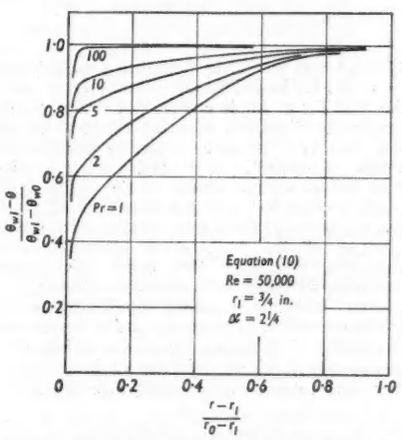


Fig. 5—Temperature profile—effect of Prandtl number

shows predicted temperature profiles for various values of the Prandtl number and a constant Reynolds number. The theory could be modified to include the transition layer and this would improve the result for higher Prandtl numbers. In its present form it is probably most accurate for gases.

The final dimensionless temperature ratio is relatively simple and easy to use and despite the discrepancy between the experimental and predicted profiles for air in Fig. 4, no attempt at improvement can be made until more experimental data with other fluids become available. In the simple analysis, both boundaries of the annulus are assumed smooth. An extension of the theory to heat flow at both boundaries would find a practical application in the heat exchanger having multiple concentric annular passages.

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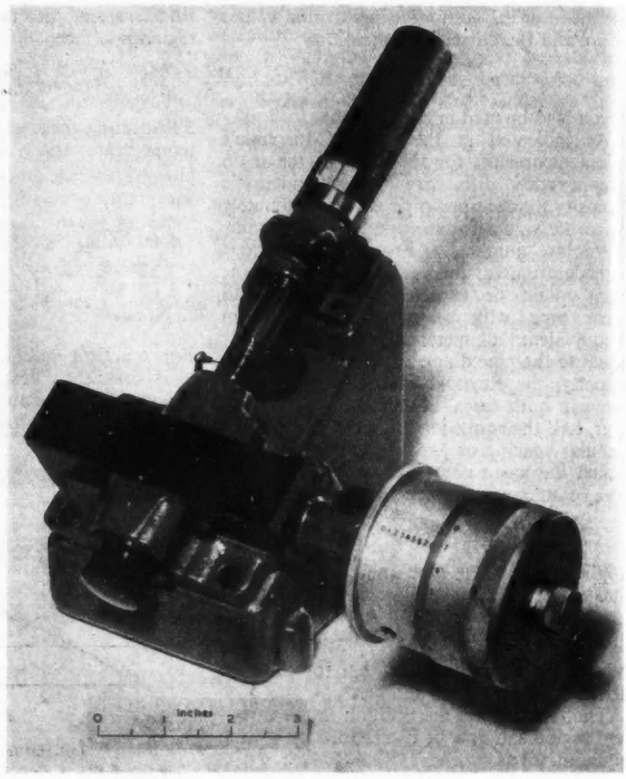
Precision Comparator for Small Cylindrical Work*

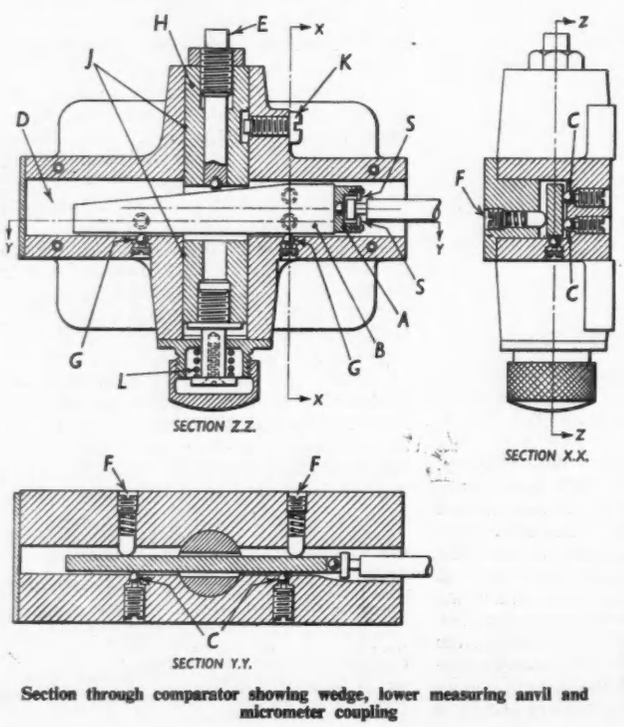
By J. C. EVANS, B.Sc., Ph.D., and W. F. ATKINS, A.M.I.Mech.E., A.M.I.Prod.E.

This article describes a simple comparator for measuring small cylindrical work to an accuracy within ±0·00001in (±0·25μ). It was primarily designed for measuring the diameters of cylinders used in determining the effective diameters of screw gauges. The work is measured by comparison with suitable cylindrical standards, work and standard being placed, in turn, between parallel flat anvils. One anvil is attached to a fiducial indicator of magnification 1000 : the other is driven by a 10 : 1 wedge which is itself driven by a large thimble micrometer head. By the use of the wedge the effect of errors of the micrometer screw are reduced tenfold. Its range of measurement is similarly reduced, but the position of the fiducial indicator is adjustable; a measuring range of 1in (25mm) is thus made available.



THE instrument to be described was designed at the National Physical Laboratory, to meet the need for a simple comparator which would enable the diameters of small cylinders to be measured by a simple technique to an accuracy within ±0·00001in (±0·25μ). It may be regarded as a development of the N.P.L.-type bench micrometer[1] designed some eighteen years ago or, indeed, of the much earlier micrometer carriage of the N.P.L.-type screw-diameter-measuring machine.[2] The bench micrometer comprises a large-thimble micrometer head and a fiducial indicator mounted collinearly in a U-shaped frame, the work being measured by placing it between the non-rotating flat-ended spindle of the micrometer head and a parallel, flat anvil attached to the indicator. It can be used generally to an accuracy of ±0·00005in; with care and by repeating observations at different positions along the micrometer screw, an accuracy of ±0·00002in may be attained. It appeared likely that the finer accuracy might be achieved without duplication of observations by introducing a 10 : 1 precision wedge which would be driven by the micrometer spindle and which, in turn, would drive an anvil to contact the work. In this way, the effect of the inherent errors of the micrometer screw, both progressive and periodic, would be reduced tenfold and the magnification, i.e. the ratio of the length of unit division on the micrometer thimble to displacement of the anvil, increased tenfold. To realise these advantages to the full, however, it would also be necessary to increase substantially the sensitivity of the fiducial indicator.

* Communication from the National Physical Laboratory.



Section through comparator showing wedge, lower measuring anvil and micrometer coupling

Accordingly, an instrument on these lines was constructed at the laboratory, primarily for the purpose of measuring accurately the diameters of cylinders used in measuring the effective diameters of screw plug gauges.[3] These cylinders range in size from 0·005in to 0·2in (0·1mm to 5mm), and a set of standard cylinders covering this range is provided for use with the instrument. The sizes of these standards are known to a few millionths of an inch from measurements made in the Sears Millionth Comparator.[4] In this latter machine, measurements are made under several different measuring forces and the size of the standard under zero measuring force is determined by extrapolation. In the instrument described in this paper, the measuring force is about 8 oz (200 grammes) weight, but this force is common to both work and standard, so that the true diameters of the thread-measuring cylinders, i.e. the diameters in the uncompressed condition, are determined—a point of some importance in the British practice for measuring screws.[5]

Description

The comparator is seen in the figure above. The various components are mounted on a base casting, the upper surface of which is sloped at about 30 deg. to the horizontal for convenience in operating the instrument. The work (a thread-measuring cylinder in the illustration) is measured between two parallel, flat anvils. The upper anvil is rigidly attached to the plunger of the fiducial indicator; the lower anvil is driven by a precision wedge mounted within a dust-proof housing, the wedge being itself driven by the micrometer head. The position of the fiducial indicator can be adjusted to accommodate cylinders of different sizes. A total measuring range of 1in (25mm) is thus provided; an adjustable table may be used for supporting the larger work during its measurement. Details of the various components of the instrument are set out below.

Micrometer Head

The micrometer head is a standard commercial product complying with the relevant British Standard (B.S. 1734 : 1951). It has a non-rotating flat-ended spindle with a range of travel of 1in (25mm). The pitch of the micrometer screw is 40 t.p.i. and the scale on the thimble, which has a diameter of 2½in (63mm), has twenty-five figured divisions, each sub-divided into ten parts; each sub-division thus represents 0·0001in (2·5μ) travel of the micrometer spindle and the magnification is 300 approximately. The corresponding movement of the lower measuring anvil (which contacts the work) is 0·00001in (0·25μ), on account of the 10 : 1 wedge, so that the overall magnification is about 3000.

Coupling Between Micrometer Spindle and Wedge

The coupling between the micrometer spindle and the wedge is a flexible one. The U-shaped body *A* of the coupling is of mild steel and is attached to the wedge *B* by means of a cold-setting resin (such as Araldite). A steel

ball pressed lightly into a central hole in the body contacts an end face of the wedge and serves to transmit the thrust between the micrometer spindle and the wedge when the micrometer is advanced. Two thin spring-steel strips, *S*, *S*, attached to the body of the coupling and sprung lightly into a peripheral groove ground in the micrometer spindle, enable the wedge to be towed when the micrometer is retracted. This form of coupling allows the wedge to take its location from the ball seatings provided (see below) and introduces no additional constraints when the wedge is being driven by the micrometer, a feature found essential for the successful functioning of the instrument.

Wedge

The wedge *B*, which has a taper of 1 in 10 along its length, is made of tungsten carbide. It was given the simplest possible form to facilitate machining and its working surfaces were ground and lapped to the required angle to about 1 second of arc in order that an exact 1 : 10 conversion factor could be applied to the micrometer readings. The wedge is supported on three balls *C* lightly pressed into holes in the bottom of the slot *D*. The positions of these balls are initially adjusted by means of the screws provided so that contact between the lower measuring anvil *E* and the working face of the wedge is made centrally along a line of greatest slope. Two spring-loaded plungers *F* in the cover-plate can be adjusted to exert just sufficient force to ensure that the wedge is held in contact with the balls. Two further balls *G* provide the reaction to the thrust of the measuring anvil and guide the wedge in its displacements.

The sleeve *H*, which carries the lower measuring anvil *E*, is a good sliding fit in the bearings *J*. It is slotted to allow the wedge to pass through it with ample clearance and the screw *K* prevents it rotating. The anvil is screwed into the sleeve and is of such length that a ball inserted in its lower end protrudes into the slot to make contact with the wedge. The pressure at the contact is controlled by the force applied by a suitable spring *L* located between the lower end of the sleeve and a flange screwed to the casting. This force, acting on the working face of the wedge, has a component which assists when the wedge is towed by retracting the micrometer spindle.

Fiducial Indicator

The indicator is mounted in a small casting attached to the main base of the instrument. The bore in this casting was lapped to provide a good sliding fit for the bearing shank of the indicator. Its axis was made collinear with the axis of the lower measuring anvil so that alignment would be preserved over the 1in (25mm) measuring range, and a tangent bolt serves to lock the indicator in any desired position without disturbing the alignment. The mechanism of the indicator is on the lines of a fiducial indicator, described earlier by Rolt and Turner[6] for use in a screw-diameter-measuring machine, but modified to give a plunger-to-pointer magnification of 1000 approximately. This is lower than the combined magnification (3000) of the micrometer and wedge but there is an advantage on the side of the indicator in that the setting is made line-to-line. As was mentioned earlier, the upper measuring anvil is integral with the plunger of the indicator.

Measuring Anvils

The contact faces of the two measuring anvils were lapped flat and parallel *in situ*. The anvils which are illustrated are intended for measuring thread-measuring cylinders or similar small cylindrical work and have contact faces of $\frac{1}{8}$in (3mm) diameter ; others with contact faces of $\frac{1}{4}$in (6mm) diameter are available for larger work.

Operation and Possible Sources of Error

An instrument of this kind is intended to be used as a comparator, the size of the work being determined by comparison with a suitable standard of similar form. The use of the wedge reduces the range of travel of the lower measuring anvil to 0·1in (2·5mm), which sets a maximum limit for the difference in diameter of work and standard. It is not, however, desirable to use this maximum difference, when it can be avoided, because error may be introduced on account of a progressive error of the micrometer screw, or because the angle of the wedge may be incorrect. The maximum progressive error of the screw allowed by the British Standard is 0·0001in (2·5μ) over the 1in (25mm) travel ; if present, this would result in an error of 10μin (0·25μ) in the corresponding 0·1in (2·5mm) travel of the lower measuring anvil. An error of 2 seconds of arc in the angle of the wedge would also introduce an error of 10μin in the displacement of the anvil. The combined error due to both sources can, of course, be determined by calibrating the instrument over the 1in travel of the micrometer spindle by means of slip gauges. The more troublesome periodic error of the micrometer screw is rendered negligible by the use of the wedge : the British Standard allows a maximum periodic error of 0·00002in (0·5μ) and this is reduced by a factor of ten.

At the laboratory, the comparator has been used with standards differing in size from the work by no more than about 0·01in and an accuracy within ±0·00001in (±0·25μ) is readily attainable under these conditions.

Acknowledgments

The comparator was constructed by Mr. G. P. Goymour and much assistance was given by Mrs. J. G. Wood during its development. The work described has been carried out as part of the research programme of the National Physical Laboratory and this paper is published by permission of the Director of the Laboratory.

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The Channel Tunnel: Will it Ever be Driven?

By ROLT HAMMOND, A.C.G.I., A.M.I.C.E.

The possibility of driving a tunnel under the Channel is now again being actively discussed. The reason for this renewed interest in an old project appears to lie in the initiation of discussions about the setting up of a European Free Trade Area, the implication being that trade between this country and the Continent may greatly expand. In this article the author briefly records the history of the project, discusses the technical difficulties and describes various proposals that have been put forward, in particular that of the Channel Tunnel Company, believed to be more practical than any other.

ONCE again the project for a Channel Tunnel is being discussed, and recently an all-party committee met at the House of Commons to reopen this highly controversial matter. A leading light in this new attack on the problem of cross channel communications is Mr. L. W. B. Teeling, chairman of the Channel Tunnel Committee and M.P. for Brighton Pavilion Division. "There is now no reason why we should not have the tunnel," he stated. "The prospect of a common market, in which Britain will have to compete, has altered the old point of view ; a tunnel is far the cheapest way of getting goods to the Continent." The project has a long and interesting history, dating back more than a century and a half, and it nearly reached realisation in 1930, when a motion for its approval was defeated in the Commons by the narrow margin of only seven votes. It is claimed that under modern conditions there are no longer serious strategic objections ; on the French side the scheme has always been supported by the Government. The estimated cost to-day is about £100 million, but in the early 1880s, when pilot tunnels were actually driven for short distances on both sides of the Channel, the cost would have been £5,000,000.

Early History

The French engineer Mathieu proposed a tunnel in 1800, but the first practical suggestions were put forward in 1867, when joint Franco-British plans were submitted to Napoleon III, who was always attracted by such ideas. On his suggestion an International Committee was formed, but the outbreak of the Franco-Prussian war in 1870 stopped further progress until the conclusion of peace in 1871, when a spate of suggestions was put forward for improving communications. These included bridges, steam ferries, tunnels, and powerful steamships with greatly improved harbour facilities, but the protagonists of the Channel Tunnel pressed forward with their plans, until eventually the Channel Tunnel Company, Ltd., was formed.

Work of the Channel Tunnel Company

In 1875, the Channel Tunnel Company obtained a local Act of Parliament enabling land to be acquired near Dover for the project, and simultaneously a concession was granted to the French company by the French Government, laying down certain conditions on which the tunnel was to be constructed. While these negotiations proceeded geological information was accumulated, the first French engineer to study the problem from this and other practical aspects having been Thomé de Gamond, who devoted most of his life to this abortive scheme. In 1866 he had proposed that the tunnel should be driven through the Wealden and Oolitic formations of the Jurassic system between Folkestone and Cape Grisnez, passing below the Varne sandbank, which is about midway between the two coasts. He intended to sink a shaft through this sandbank, and a shaft on each side of the Channel, so that tunnel driving could be carried on from four faces instead of two, and thereby accelerate construction. Sir John Hawkshaw, a leading British civil engineer of his day, pursued parallel studies of the geological problem ; in 1865 he instructed Mr. Hartsink Day to study the cretaceous and underlying strata on both coasts.

Surveys of Strata

This survey was immensely valuable, because it proved conclusively that the chalk overlying the gault is almost the same on both shores, but in order to examine the strata composing the sea bed a special sounding apparatus was designed. With its aid the specimens brought to the surface from the bottom of the sea were claimed to prove the

continuity of the cretaceous beds across the Channel for the whole of the proposed route. Sir John Hawkshaw was a very thorough engineer, who was not satisfied with mere identification of the strata as exposed on the cliffs on each side of the Channel, and their superficial continuity on its bed. He therefore put down two borings, one at St. Margarets Bay, 8 miles east of the lowest chalk stratum on the English coast; and the other on the French coast at Ferme Mouron, 4 miles east of the outcrop of the same stratum on the French coast. These borings proved that the thickness of the lower chalk does not diminish to any marked extent as it is traced eastwards from the outcrop.

Preparatory Works

In 1881 the South Eastern Railway Company obtained powers to acquire land for experimental borings and other works. This company also carried out experimental work in connection with the proposed construction between Folkestone and Dover, where three shafts were sunk, one near Abbots Cliff, one near Shakespeare Cliff, and a third to the east of Shakespeare Cliff. Headings were driven from the first two shafts in a direction roughly parallel with the cliff, through the lower beds of grey chalk, and for some distance under the sea. The author has visited Shakespeare Colliery, the site of one shaft.

Tunnel Driving Difficulties

It would certainly appear that there should be no difficulty about driving the tunnel, but if there is one thing certain about tunnelling it is its uncertainty, and there is absolutely no guarantee that it can be driven for about 24 miles under the sea without meeting fissures and infilled valleys not yet revealed to the geologists. Although grouting and freezing could be used to surmount this problem, compressed air would be out of the question because the pressure would have to be so great as to make this method impracticable. Cementation at high pressure might be feasible, but only where the grout would be certain of penetrating the voids in the waterlogged material; in the case of a valley filled with fine sand, it is doubtful if this method would succeed, although possibly chemical injection using the Joosten process might be the answer.

In any case, from the purely constructional aspect, it is improbable that the difficulties would exceed or even approach those successfully overcome by Sir Francis Fox, when the famous Simplon Tunnel was driven through the Alps.* To show how difficulties can be overcome it is worth entering into some detail about the construction of the Simplon Tunnel. In November, 1901, the advanced gallery on the Italian side of this 12½-mile tunnel entered a formation of calcareous mica schist completely decomposed; the drills had to be withdrawn, and work proceeded by hand. Heavy and close timbering of the whole gallery, on both sides, as well as on roof and floor, had to be done at once; although whole timbers were used, they were crushed by the enormous pressure, and for the time the heading was lost. The miners were withdrawn, and a fresh start was made by inserting rolled steel joists, 16in deep, bolted together, with baulks of pitch pine 20in square in cross section between them. The heavy pressure deformed this girder work, shearing the bolts and crushing the timbers into splinters. As a last resort, the space between the beams was rammed with quick-setting concrete, and this held. Fortunately, the wagon road had been maintained, and access was secured for the drill to go ahead; after a delay of six months, the advance was resumed. After eighteen months of gruelling work, the permanent tunnel lining was made secure with granite blocks set in cement mortar, at a cost of £1000 per lineal yard.

In consequence of this delay, the Swiss headings had reached the culminating point at 5 miles 1670 yards from the Swiss portal, which had been laid down as the boundary for the workings on that side. In order to save time, however, it was decided to drive forward as far as possible on a slightly rising gradient, until the top of the future tunnel was reached, by which a point at 6 miles 350·4 yards from the portal was attained on October 10, 1903. Here it was impossible to continue further on an upward incline; it was therefore decided to drive downhill, on a gradient of 1 in 40, to meet the miners coming uphill from the Italian side. The very problem which the ascending gradients were planned to avoid had now to be faced.

The heat was almost unbearable, the maximum temperature 133 deg. Fah., and as the galleries advanced downhill hot springs followed; the miners with their drills stood in a sea of hot water. For a time this was pumped out over the apex of the tunnel by centrifugal pumps mounted on travelling carriages; but at 6 miles 541 yards the downhill advance could not be continued. Yet time had to be saved, and as the height of the finished tunnel would be about 14ft above the top of the gallery, it was arranged that the heading should be continued; it was therefore driven on a rising gradient of 1 in 1000.

Meanwhile, strong iron doors were fixed in both headings at 6 miles 517 yards, which could be closed in an emergency to hold back the hot water. Since actual pressure likely to be encountered was unknown, a relief main with valves was provided, delivering the hot water over the apex of the headings at 5 miles 1670 yards. With tremendous courage and determination, a further advance of 273 yards was made; centrifugal pumps ejected the hot water and threw cold water into the fissures. This hot water amounted to 1188 gallons per minute. All hope, therefore, centred on the Italian advance, and on February 24, 1905, the final holing through took place. When the final charge was fired in the gallery, a large volume of hot water rushed out, which took half an hour to escape. The last 245m of gallery had taken nearly six months to complete, owing to these unprecedented difficulties. This was probably the most difficult tunnelling work ever carried out.

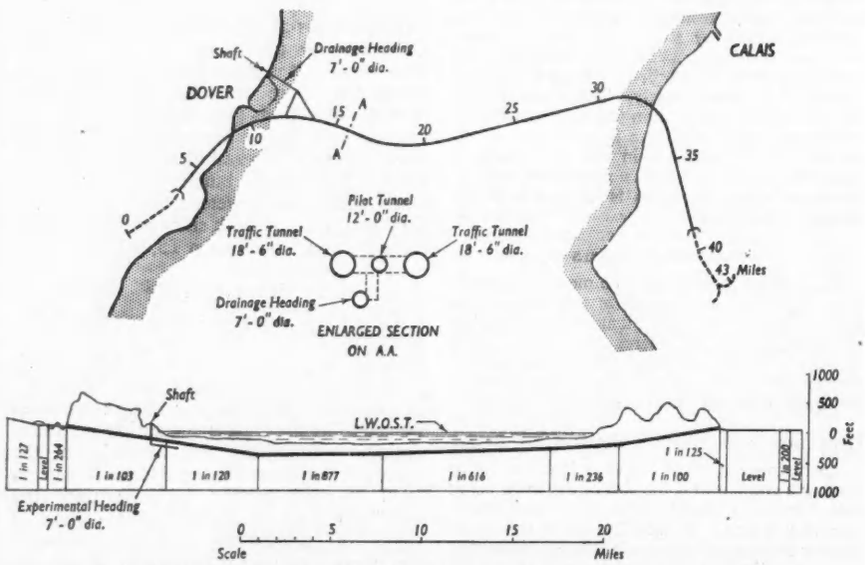
Military Objections to the Channel Tunnel

The year 1880 is an important landmark in Channel Tunnel history, because in that year military objections were first raised. These objections led subsequently to the appointment of a Joint Select Committee of both Houses of Parliament, and by a majority of six to four in April, 1883, the members merely gave an opinion against Parliamentary sanction for the scheme. Lord Lansdowne, the chairman, was in favour of the tunnel. However, in spite of this adverse opinion, the project was brought forward eleven times in the next twelve years, but on each occasion without success owing to military objections.

Various Alternative Schemes

The great advantage of a tunnel from the passenger aspect is the direct express journey from London to Paris, eliminating delays of embarking and disembarking, the journey time being still further reduced by arranging for Customs and other formalities to be carried out on the train. Although fine ships and gyro-stabilisers have done much to make the sea passage more comfortable than hitherto, the fact remains that it can still be extremely unpleasant, and bad weather still causes delays. The ferry is perhaps more successful than the ordinary sea passage in eliminating transhipment, and ensuring more rapid delivery of perishable goods, and its initial cost is very much less than that of a tunnel.

Several interesting alternative schemes have been proposed for improving cross-channel communications, but all suffer from grave technical disadvantages. A recent proposal by Monsieur André Basdevant for a combined road and rail tunnel is quite inadmissible, mainly because of the extreme difficulty of providing adequate ventilation to drive carbon monoxide from a tunnel of such great length. Moreover, an accident occurring to road vehicles anywhere in the tunnel would immediately cause immense confusion.



Route of tunnel shown in full line, dotted lines indicate connections with existing railways in cuttings.

Fig. 1—Sketch map and longitudinal section of proposed Channel tunnel, based on the report of the Channel Tunnel Committee, March, 1930

* "The Simplon Tunnel," by Francis Fox, M.I.C.E. Paper No. 3651, *Proc. Inst. C.E.*, Vol. 168, 1907.

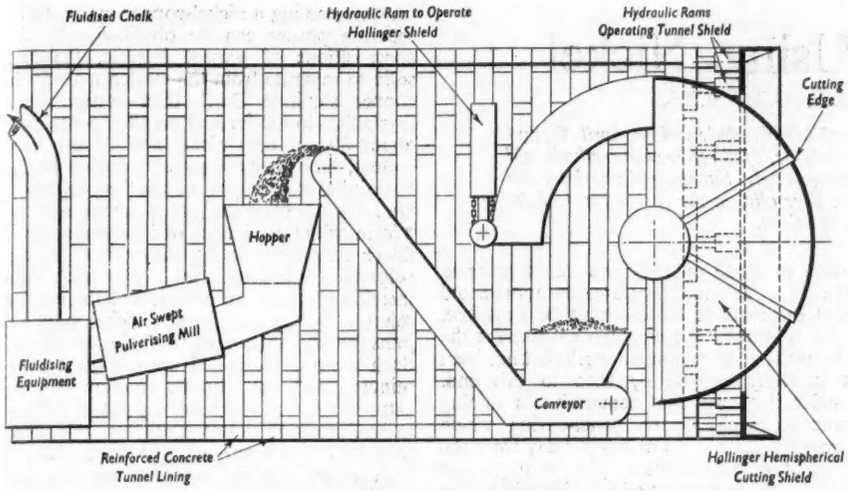


Fig. 2—Sketch showing a suggested method of driving the twin track and pilot tunnels, removing the excavated chalk in the form of a fluidised powder

A scheme for a Channel bridge was put forward by Sir Murdoch Macdonald and Partners in collaboration with Monsieur Huguenin. This design was for a bridge spanning the 22 miles between Folkestone and Cape Grisnez, carrying a double railway track for most of its length, with a passing station having four lines of track over a length of 3 miles about midway across the Channel. It was further proposed that there should be a roadway for motor vehicles, 33ft wide above the railway tracks, to carry four lines of traffic. Navigational requirements would be satisfied by a clearance of 200ft above high tide for a length of 10,000ft, equivalent to five spans, each of which would be 2000ft. It was claimed that such a bridge would not be a serious obstacle to navigation ; each span would be of continuous suspension type with inverted three-hinged trusses and cable wind trusses. There would be twenty-six spans on the British side and twenty-seven on the French side, total estimated cost in 1930 having been £75,000,000 ; estimated revenue was given as £9,000,000, which was regarded as adequate to cover cost of operation and maintenance, in addition to providing a reasonable return on capital expended. Although this scheme might be practicable, the gravest objection is obstruction to navigation. For most of the distance piers would have to be sunk in the high seas, and it might be extremely difficult to obtain international agreement for their erection.

An Italian expert suggested the construction of a submerged railway tube on the sea bed, the inventor having claimed that this would be rigid and watertight while on the bottom, yet flexible enough to be capable of being raised to the surface at any point for repairs. Cost in 1930 was estimated at £2,000,000. Two towers rising above the surface would provide for ventilation and would also be obstructions to navigation. Neither this nor a scheme for a cross-channel jetty can be regarded as practicable. The latter, proposed by a Swiss engineer, envisaged the construction of two dams from Deal to Calais at a cost of £80,000,000, each carrying two railway tracks and a motor road. The water enclosed between the two dams would form a large canal.

Another scheme was that put forward by Mr. William Collard, governing director of the London and Paris Railway Promoters, Ltd. The proposals of the latter company included acquisition of the rights of the Channel Tunnel Company, construction of a Channel Tunnel and the provision of a 7ft-gauge railway to enable the journey from London to Paris to be accomplished in under three hours. Total estimated cost in 1928 was £100 million, and Mr. Collard took some fourteen years (1914–1928) to write a book on this project. The author once met the late Mr. Collard, but was unable to convince him that his entire scheme was based on the fallacy that a broad gauge was desirable.

Scheme of the Channel Tunnel Company

From the technical point of view the scheme of the Channel Tunnel Company is by far the most practicable, and it was Sir Francis Fox, profiting from his experience gained on the construction of the Simplon Tunnel, who proposed that twin single-track tunnels should be driven through the chalk, connected by cross headings at regular intervals. This contributes towards safety during construction and ventilation during service.

Disposal of the immense quantity of spoil produced is a problem which has received careful study, and the scheme put forward by Monsieur Javary is worth consideration. He suggested adoption of the Fougerolles system of disposal, in which a rotary tunnelling machine similar to the Price excavator used on the London tube railways, would be employed, the debris from which would be mixed with water to form a slurry which could be pumped through boreholes to the sea bed. This would undoubtedly effect great economies in tunnel driving, but considerable research would be necessary to determine whether the scheme would be practicable.

The Channel Tunnel Company's scheme envisages two independent traffic tunnels, each of 18ft 6in diameter, together with permanent pilot and drainage tunnels, as indicated in Fig. 1. The drainage tunnel will be of 7ft diameter and the pilot tunnel of 12ft diameter ; the driving of this would not only prove the practicability of the scheme, but would also provide for exploration of the adjacent ground by borings. The author believes that the Hallinger patent shield of spherical design (Fig. 2) could be used and that the chalk could be removed in the form of a fluidised powder through pipelines. Cement works could be established on each coast and precast reinforced concrete segments made for lining the tunnels.

Economics and Strategy

Let us suppose that a Channel Tunnel is practicable, which is still very doubtful. Is the projected £100 million expenditure going to be justified, and is the strategic risk really so small ? We can imagine how eagerly the bullet-headed members of the German General Staff would have welcomed the existence of a tunnel in 1939 ; a determined paratroop attack on each portal, the establishment of a bridgehead on each coast for only twenty-four hours, and we might have been done for. Moreover, this enormous capital sum could probably be put to far better use in improving existing services, which, in spite of their shortcomings, can readily be adjusted to traffic needs. It has yet to be proved convincingly that the proposed tunnel will really attract that extra traffic which will justify its construction, and there is still much to be said in favour of the defensive benefit of 20 miles of sea.

Future Possibilities

The most interesting recent development in this project has been the announcement that the Suez Canal Company is considering the matter. Discussions have just taken place between Monsieur Jacques Georges-Picot, director-general of the Suez Canal Company, and Mr. Leo d'Erlanger, chairman of the Channel Tunnel Company. The cost of a geological survey has been estimated at between £250,000 and £275,000, and a syndicate will be formed consisting of the Suez Canal and Channel Tunnel Companies, with British and French Railways and British, French and American banks.

On a recent visit to Kelvin Hughes, Ltd., the author was told that modern echo-sounding equipment could reveal the presence of mud or silt in the Channel to a considerable depth ; this would be most useful in revealing fissures and infilled valleys, which could then be further explored with special sounding apparatus used to retrieve samples.

The pilot tunnel could be used in connection with a scheme put forward towards the end of 1956, sponsored by a joint committee of the Central Electricity Authority and the Electricité de France, for linking up the electrical power networks of both countries. This envisages the interchange of energy by means of a single cable capable of transmitting between 120MW and 150MW at a pressure of 200kV ; estimated cost was given at £4,000,000 and the completion date as some time in 1960.

If such a cable were laid in the pilot tunnel of a Channel Tunnel, no special risks due to navigation and fishing would have to be considered ; moreover a cable laid in the tunnel would be cheaper than an equivalent submarine cable laid on the Channel bed. In addition to this power cable, there would certainly be ample room in the pilot tunnel for further cables to meet increased demand, and all these cables could be maintained easily at low cost. In addition, oil and possibly natural gas pipelines could also be accommodated in the tunnel, the income from such services being a great advantage to the promoters of a Channel Tunnel in the early stages of its construction.

Glass Fibre Aircraft Seat.—A prototype aircraft passenger seat in glass fibre reinforced plastic has been made by Microcell, Ltd., to a Ministry of Supply specification, for a two-place tourist seat. The use of a relatively small number of components bonded together resulted in a saving of weight, the protype weighing 36 lb, while a metal seat might have been 51 lb. It is expected that the plastic construction will prove safer in the event of a crash, the legs allowing some inches of yield under high accelerations, and the edges of a fracture in the material being soft rather than sharp. The seats have been tested up to 10·8*g* forwards, allowing a margin over the 9*g* requirement of 1·2 for material scatter. It is believed that a seat to face rearward could be made for 42 lb.

Refining and Using Nickel

By L. B. PFEIL, O.B.E., D.Sc., F.R.S.

In his presidential address to the Institute of Metals, delivered on April 30, and from which the following material is abstracted, Dr. Pfeil referred to methods, old and new, of reducing nickel ores and of refining nickel. Subsequently he described shortly some of the uses of nickel, referring, inter alia, to the development of the Nimonic series of alloys.

IT is, of course, well known that Canada is the principal source of the metal, nickel, with the major developed ore deposits lying in the Sudbury area of Ontario. Here the nickel occurs as sulphide, as also does copper, each to the extent of roughly 1 per cent in the ore mined. Essentially the treatment of the ore consists of crushing and grinding, differential froth flotation of the sulphide, smelting the nickel-rich concentrate to give a nickel sulphide matte containing some copper sulphide, separating the nickel sulphide from the copper sulphide, converting the nickel sulphide to oxide and, finally, refining to give electrolytic nickel or Mond pellet nickel. Nickel sulphide (pentlandite) commonly occurs in association with much larger proportions of iron sulphide (pyrrhotite). Pyrrhotite is magnetic, and this property has played a significant part in recent years in facilitating the search for new ore-bodies. A large mass of magnetic iron sulphide, even at a considerable depth in the earth's crust, can influence the instrument known as the magnetometer.

Prospecting for Ore

In so vast a country as Canada, prospecting by teams of men on the ground is slow and costly in labour. The introduction and development of airborne geophysical exploration by magnetometer inspection followed by the use of airborne electromagnetic gear, which records data on the electrical conductivity of rock formations, are of particular interest in that these procedures have brought about a major change in the speed and cost of prospecting. An aircraft carrying recording geophysical instruments, together with a synchronised cine-camera, is flown at a low height across the territory along paths about half a mile apart. In some circumstances, for example, when flying over water, radar may be used so that the location of magnetic and other anomalies can be accurately plotted. The records obtained are studied and areas of possible interest are delineated on the map. Subsequently, prospecting teams on the ground investigate the selected areas by diamond drilling and the like.

To provide some quantitative indication of the importance of airborne prospecting, figures may be quoted for the work carried out by The International Nickel Company of Canada. It has been reported that, in a single year, 24,000 miles were flown and, during the past ten years, nearly £1,000,000 has been expended by the company on airborne exploration. This, of course, is only a part of the story, for in this same period the company spent a total of more than £10,000,000 on exploration for new nickel deposits. The detection of anomalies is a far cry from finding nickel ore or, indeed, from demonstrating that anything of value is in the offing. Experience proves, however, that exploration for nickel in the region of certain types of anomaly is much more likely to be successful than elsewhere.

Treatment of Nickel Ores

The major nickel deposits now being mined in the Sudbury area are substantially lower in grade than the ore mined prior to the war. It will, therefore, be appreciated that the costs of mining must be kept low. This is scarcely the occasion to describe the research and development work that has been successfully applied by Inco to this end. Suffice it to say that economies in mining practice, such as the panel-caving which provides 10,000 tons of ore per day from the Creighton mine, have played an important part in the prosperity of the nickel industry.

In concentrating these low-grade nickel ores froth flotation plays a vital role. For more than fifty years it has been known that, when finely-ground ore is suspended in aerated water, some minerals are readily wetted and sink, while others, being air-avid, will adhere to air bubbles and be carried to the surface. In recent years much research has been carried out bearing on this phenomenon: for example, studies of "promoters," which alter the wettability of the mineral particles (I avoid the terrible word "hydrophobicity"). Again, research has been active on frothing agents, which help the formation of stable air bubbles of the desired size, while numerous other variables have received attention, such as acidity, temperature, particle size and surface texture of the minerals. Such research and development has made it practicable and economical to separate the finely-ground Sudbury ore into four fractions :—

A nickel-sulphide-rich concentrate.
A copper-sulphide-rich concentrate.
An iron-sulphide-rich concentrate.
Waste rock—of no value.

Discarding the rock waste at an early stage and sending the bulk of the iron to a separate circuit not only greatly reduce the weight of material to be smelted, with a saving in cost and increase in useful smelter capacity, but have led to the marketing of a premium grade of iron ore made from the iron sulphide, which iron was formerly converted into slag and dumped.

Separation of Nickel, Copper and Iron

It is not practicable, by the differential froth flotation of Sudbury nickel-copper ores, to obtain nickel sulphide completely free from copper, and the more complete separation of these two metals is an essential further step. The classical treatment for the separation of nickel sulphide from copper sulphide is that known as the Orford process, in which the first step is smelting to produce a molten nickel-copper-sodium-sulphide matte. Such a matte separates, on cooling, into two layers—the upper layer consisting of copper-sodium-sulphide and the bottom layer of nickel sulphide. To obtain nickel substantially free from copper, the separation process has to be repeated, thus rendering the treatment complicated and expensive.

In the Copper Cliff smelter of the International Nickel Company, the Orford process has been replaced by the so-called controlled-cooling process, which is a major improvement in smelter practice. The fundamental background of the process is exhibited by the nickel-copper-sulphur ternary equilibrium diagram which demonstrates that, on slow cooling a nickel-copper matte, three separate phases can be obtained. In the compositions of present interest, the first solid to separate from the molten material is copper sulphide Cu_2S, then actual metal crystallises in the form of an alloy containing about 80 per cent nickel and 20 per cent copper, and finally α nickel sulphide Ni_3S_2, containing some copper in solution, solidifies. On further cooling the α Ni_3S_2 changes to the β form, with the rejection of dissolved copper. Given very slow cooling, the primary copper sulphide forms in large crystallites; the metallic particles are coarse, and the copper rejected by the transformed nickel sulphide joins the primary copper-sulphide crystallites. Such a slowly solidified mass may be comminuted and the metallic fraction can be extracted by a magnetic separator. As a bonus, precious metals, platinum, gold, &c., join the metallic portion, which may be less than 20 per cent of the whole, and are thus readily amenable to early recovery. By employing froth flotation the nickel and copper sulphides can readily be separated with a mutual contamination not exceeding 1 per cent and its introduction and the elimination of the Orford separation can fairly be described as a milestone in the progress of the nickel industry.

Oxygen Flash-Smelting

The refining of nickel in the Sudbury ores cannot be dissociated from the refining of copper, since these two metals occur in about equal quantities. An interesting innovation in recent years has been the oxygen flash-smelting of the copper-sulphide concentrate. The sulphide is treated as if it were pulverised coal and is blown into the furnace with oxygen and flux. The burning of the iron and sulphur in the concentrate provides sufficient heat to give a molten copper-sulphide matte and an iron-rich slag. Apart from the saving of fuel, this process yields a gas so rich that liquid sulphur dioxide can readily be condensed out, and this product is of great value in the important Canadian paper pulp industry. The magnitude of this flash-smelting operation may be judged from the fact that more than 100,000 tons of oxygen and 70,000 tons of liquid sulphur dioxide are produced annually, with a saving of 60,000 tons of coal.

Recovery of Iron

The most recent change in Copper Cliff refining practice has been the setting up of a separate circuit for the iron-rich flotation concentrate. The treatment is designed not only to produce a high-grade iron ore for steelmakers, but to recover the nickel values in the iron sulphide. The iron sulphide is fluid-bed roasted to oxide : air is blown up through a bed of the hot sulphide so that no mechanical stirring or raking devices are required. The finely divided oxidised material is carried away by the gas stream, collected in a cyclone, and then fed into a reduction kiln, where conditions are so adjusted that nickel, but only a little iron, is reduced. Then follows an atmospheric ammonia-leaching treatment whereby the nickel is dissolved, to be recovered later as nickel carbonate. Finally, the iron oxide is pelletised, to give walnut-sized material particularly suitable for adding to steel furnaces. This passing reference to the recovery of iron ore and nickel by leaching is only one example of the current importance of hydro-metallurgy in nickel extraction. Other outstanding examples of such processes are those which are employed by the nickel companies in Cuba and by Sherritt Gordon in Manitoba.

Whereas a considerable amount of nickel is marketed as oxide—a form which can readily be used by steelmakers—the bulk of the production is further refined, either electrolytically or by the Mond carbonyl process.

Applications of Nickel

I think that few of you will quickly be able to think of an application where nickel can be seen in service, and perhaps I may say, without being accused of advertising, that nickel has been described in the course of sales development as "Your Unseen Friend." There are some, but relatively few, exceptions to this "unseen." There are pure nickel coins in circulation, but not in this country, and there is a widespread use of nickel for saucepans and the like, but in hotels rather than in private homes. Nickel parts can be found in radio valves, nickel equipment is used in some types of chemical processing plant, and a peculiarly interesting use of nickel which has more recently been developed is its application in echo depth-sounding equipment, where the unusual magnetostrictive properties of the metal are utilised.

Nickel Alloys

Nickel is, however, essentially an alloying element, the introduction of which into other metals leads to the development of alloys possessing special properties. Outstanding examples are the austenitic stainless steels, generally containing 8 per cent nickel and 18 per cent chromium. Because of their special properties, the demand for these steels has been steadily increasing over the past few years and at the present time about one-third of all the nickel available in the free world is so used representing the largest consumption of the metal in any single field of application.

Stainless and Constructional Steels

The chemical industry, which demands highly corrosion-resistant materials, has for a long time made extensive use of stainless steels, and in recent years such materials have played a prominent part in atomic energy developments. The food industry and the domestic field are making increasing use of stainless steels and, looking to the future, it seems likely that important advances will be made in their adoption for architectural purposes. Second only to stainless steel is the use of nickel in constructional alloy steels, an application which until recently has been the biggest single consumer. It was recognition of the fact that the addition of nickel to steel gives a stronger and tougher product which, some sixty years ago, stimulated increased nickel production and, over the years, has been largely responsible for the development of the industry. It is interesting to note that the favourable influence of nickel in alloy steel, now couched in terms of hardenability, depth hardening, and transformation characteristics, was recognised by much more "rule-of-thumb" methods so long ago.

The situation which has now existed for some years, whereby the demand for nickel has exceeded the supply, has naturally led to the exercising of the greatest possible economy in its use. As a result of extensive research work on alloy steels, both here and abroad, we now know much more about the fundamental effects of nickel, both alone and in combination with other alloying elements, such as chromium and molybdenum. So much so, that double- and triple-alloy steels containing lower amounts of nickel have largely superseded the straight nickel steels previously used.

It would, however, be incorrect to generalise too widely on this tendency for reduced nickel contents; where particularly onerous service conditions obtain, such as, for instance, in the case of heavy-duty gears, preference is still given to the higher-nickel steels, containing up to 4¼ per cent nickel.

Plating

A further field which has undergone some interesting changes during my years in the nickel industry is that of plating. The amount of nickel now used as an electro-deposited underlay to chromium is estimated as some 15 per cent of the nickel available in the free world. Since the chromium coating is so thin—10 millionths to 20 millionths of an inch—it provides little more than a tarnish-resisting bright surface. The function of the nickel undercoating is to protect from corrosion the baser constructional metals which give the parts the required strength and rigidity. During recent years the study of nickel plating on a more fundamental and scientific basis has resulted in a better appreciation of the characteristics required of the electrodeposited metal, and of how to control production operations so as to obtain the best results. Unfortunately, the shortage of nickel in recent years has rendered it impossible for electrodepositors to adopt the recommended specifications for nickel plating and hence we have seen abnormally early deterioration of chromium plated parts exposed to the rigors of the British climate.

Development of Nimonic Alloys

Perhaps the use of nickel in which I have personally been most interested is that in gas turbines, where components have to function under high stresses at temperatures above a red heat. My particular interest stems from researches I undertook between 1920 and 1930 on the fundamentals of scaling at high temperatures. After 1930 I became increasingly involved in researches on nickel-chromium alloys, with special reference to the wire which is used in electrical heating appliances. In the 1930s it seemed rather surprising when researches showed that elements present in no more than traces could play a vital part in determining the heat-resisting qualities of an alloy. Less than one part in 1000 of cerium (a component of the lighter flint) was found to increase the test life of 80/20 nickel-chromium wire for domestic electric heaters by a factor of ten. How often does anyone experience a failure of an electric fire to-day—except by knocking it over, and the like?

The realisation of the significance of minor elements, in modifying the properties of the nickel-chromium alloys of this kind was, however, destined to prove much more widely applicable, and the successful development of the aircraft jet engine was closely associated with the development of alloys based on the 80/20 nickel-chromium alloy for electric fires. Obviously this material would not burn away or oxidise appreciably at high temperatures, but it is not strong enough to resist the high stresses to which jet engine components were subject, and some means had to be found to make the alloy stiffer at high temperatures without rendering it impossible to fabricate complex components by forging and rolling. The solution was found by the introduction of additional elements that rendered the alloy precipitation hardenable. At the forging temperature the modified alloy is single-phase and soft; at the somewhat lower temperature involved in jet engine service precipitation of a second phase occurs, giving the desired stiffening effect. Thus came into existence the Nimonic series of alloys—electrical resistance wire material stiffened by the introduction of titanium and aluminium.

There have, of course, been subsequent developments. The designers of jet engines and gas turbines continually demand improved alloys for operation at higher temperatures, and research has been active in high-temperature materials all over the world. The merits of further additions, such as cobalt and molybdenum, have been ascertained and commercial developments have followed.

Influence of Trace Impurities

Great interest and considerable technical importance lie in research results which have been obtained in this field regarding the influence of trace impurities. Advances which have been made in the purity of raw materials, the development of spectrographic techniques and the introduction of the mass spectrograph for the analysis of alloys and improvements in vacuum melting and casting have made researches on trace elements practical and effective. In the heat-resisting alloys there are two sorts of trace elements—the good and the bad. Amongst the good, reference has already been made to cerium; one could add zirconium, calcium, thorium and boron. On the bad side, lead, tin and bismuth might be scheduled, together with sulphur and selenium. Maybe research will show in the future that there is a third kind of trace element—the inert, but it is abundantly clear that trace elements in general play a vital part in the quality of many metallurgical products. Control over these effects falls into the field of "know-how" and can scarcely be taken into account in specifications.

Effect of Nuclear Power on C.E.A. 275kV Transmission System

It is evident that the implementation of the Government's enlarged programme for the building of nuclear power stations to provide the power demand in the next decade will have far-reaching effects on the power station construction programmes and the bulk transmission schemes of the Central Electricity Authority. Whereas the earlier plans provided for large-scale generation in the relatively cheap coalfields of the East Midlands, from which electricity in bulk would be transmitted to the south and the principal industrial areas of the country, the requirements for nuclear power stations are such that the earlier stations at least will be sited on the southern and south-western coasts of the country. Considerable replanning of the national transmission system will, therefore, be necessary.

We learn from the Central Electricity Authority that one of the first effects of this reorientation is the decision to suspend, for the time being, the project to build a 275kV line from Drakelow power station, near Burton-on-Trent, to the sub-station which is now being constructed at Fleet in Hampshire. It is explained that the line was part of the basic plan for meeting the growth in the demand for electricity in southern England, particularly in the London region. When the plan was made, the absence of locally produced fuel in the south and western Home Counties made it economically desirable to locate power stations on sites on or close to the coalfields and to transmit the energy by overhead lines.

Reappraisal of the national plan for power in the light of the nuclear power station construction programme indicates that the need for the transmission of power from the Midland coalfields to the south will not exceed the capacity of the three other 275kV links between the Midlands and the south for some time to come. Of these links, one is already in commission, the second is under construction, and the third is due for completion in 1959.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

LET'S FORGET THE CYCLOID TOOTH

SIR,—My reply to Mr. Lindsay's question as to how I would " start designing a system of involute gears without assuming an imaginary pitch or rolling circle," is that I should concentrate on the one unavoidable diameter, which is that of the blank in which the teeth are cut. A 10 D.P. gear (i.e. one generated by a 10 D.P. cutter) with t teeth may have any tip diameter between

$$\left.\begin{aligned}&\frac{1}{10}\left(t+4-\frac{A}{t}\right)\\ \text{and}\quad&\frac{1}{10}\left(t+4-\frac{t}{A}\right)\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (1)$$

where A is a constant which happens to be about 10 for teeth generated by B.S. cutters.

If $t=20$, the limits of blank diameter are :

$$\frac{1}{10}\left(24-\frac{10}{20}\right)=2{\cdot}35 \text{ and } \frac{1}{10}\left(24-\frac{20}{10}\right)=2{\cdot}2$$

The designed centre distance for gears of blank diameters d_b and D_b is

$$\tfrac{1}{2}(d_b+D_b)-\frac{2}{D.P.} \quad . \quad . \quad . \quad . \quad (2)$$

For two twenty-tooth 10 D.P. gears the designed centre distance may be anything from

$$\tfrac{1}{2}(2{\cdot}35+2{\cdot}35)-\frac{2}{10}=2{\cdot}15$$

to

$$\tfrac{1}{2}(2{\cdot}2+2{\cdot}2)-\frac{2}{10}=2{\cdot}00$$

i.e. 0·2 less than the blank diameter, whatever it is.

These gears, or any others generated by 10 D.P. cutters sunk to standard depth in blanks of diameters in the range (1) will mesh correctly together at centre distance (2) because, as Mr. Lindsay says, they all have the same base pitch. To calculate this, or the base diameters or the working pressure angle, neither helps nor hinders manufacture or operation of the gears.

W. A. TUPLIN

Sheffield,
April 26, 1957.

TVA COSTS AND PRICES

SIR,—In your recent article on the TVA, specifically, in the April 5 issue on page 546, certain comparisons are made between average domestic consumption and cost per kWh in the TVA area and the United States as a whole. I hope you will permit me to call the attention of your readers to one of the reasons for the comparatively poor showing of the remainder of the U.S.A. that is mostly supplied by independent power companies. The figures in the table below are quoted from official operating reports of the two respective organisations for 1956. They reveal the rather startling facts shown.

In other words, a giant, blessed with very low " taxes " that have to be made up by the rest of the country's taxpayers, and not depending on moneys that have to be raised in the open market, can well afford to undersell its colleagues elsewhere in the country. If the Government were to manufacture automobiles on a similar basis for half price, what chance would Ford, General Motors and others have ?

GEORGE L. SCHLAEPFER

Detroit 36, Michigan,
April 30, 1957.

The independent power company that serves me		TVA (government) power operation	
Kilowatts installed at end of 1956	2,841,000kW	End of fiscal 1956	9,279,485kW
Kilowatt-hour sales to ultimate consumers	11,502,994,566kWh		53,845,388,000kWh
Taxes (including provisions for deferred income tax)	$45,106,209	In lieu of taxes	$4,147,654
Interest	$12,733,565		$41,843
Dividends	$22,253,585		None
	$80,093,359		$4,189,497

CULTURE—THE SCIENCE MUSEUM

SIR,—With reference to your editorial in the issue for March 29, 1957, should you not have seen the Deutsches Museum in Munich, I would draw it to your attention as one which combines interest for the layman and instruction for the student with historical record in a most entertaining way. In the Electrical Section, for example, the layman can try his strength by using a hand-driven generator to light a lamp ; the student can study two models, one mechanical and one electrical, demonstrating zero sequence currents ; and the historical exhibits range from a copy of Faraday's original apparatus on magnetic induction to an actual insulator string as used for 380kV transmission. At frequent intervals a million-volt impulse generator is employed in a spectacular demonstration of how faulty earthing of a lightning conductor can result in a fire in a farmhouse.

I regret that time did not permit me to visit the Mechanical Section.

I.E.C. DELEGATE

London, May 6, 1957.

110 M.P.H. ON WESTERN REGION

SIR,—In the recent article in your journal by Mr. O. S. Nock, the claim is made that a modified " King " class locomotive achieved a maximum speed of 110 m.p.h. on a normal service run on the descent to Curry Rivel Junction, near Taunton. It is very surprising to read of such an outstanding claim without adequate supporting evidence, such as a dynamometer car record and/or passing times taken with a stop-watch over the stretch concerned. The omission is the more surprising, since Mr. Nock is an acknowledged expert on this subject, whose information one would not normally query, but in this case the locality over which the record is claimed is not one which, it might be imagined, was conducive to such high speeds, particularly with a normal service load, so that the need for supporting figures is greater than usual.

It is considered to be of paramount importance in the aeronautical, automobile or athletic world to check every record made with great precision, and in the case of the two pre-war railway records made by the former L.M.S. and L.N.E. railways very adequate figures are available. It is all the more disappointing, therefore, that on what may have been a historic occasion on the Western Region what might conceivably be actual fact is, in effect, a vague legend.

I am well versed in the art of train timing and only too conscious how great the need for very high accuracy is at very high speeds. Thus, until I see a record of passing times between quarter mileposts to the nearest one-fifth of a second over the stretch of line from Somerton to Athelney, or a dynamometer car trace, I must regard this particular record as " not proven."

W. J. ALCOCK, G.I.Mech.E.

Copthorne, Sussex, May 2, 1957.

Book Reviews

The Electrical Production of Music. By ALAN DOUGLAS. Macdonald and Co., Ltd., 16, Maddox Street, London, W.1. Price 28s.

THE subject of this book must not be confused with the electrical reproduction of music by disc, tape or sound-track. The author is concerned with instruments, most of which require performers, in which musical tones are electrically created. A loud-speaker renders these tones audible.

The present book differs from the same author's *Electronic Musical Instrument Manual* (Pitman) in that here the emphasis is on principles rather than on the electrical and mechanical details of specific instruments. Since, rightly or wrongly, electronic musical instruments are largely (though not entirely) concerned with the imitation of the sounds of traditional instruments, Mr. Douglas devotes the first eighty-four pages to a discussion of the physics of these instruments. Convenient though it is to have this substantial résumé as a prelude to the main business of the book, it must be admitted that the author has tried to cover too much ground. It would, for example, have served the purpose of the book better if a more specific discussion of the relationship of musical tone and harmonic distribution had occupied much of the space devoted to more purely musical topics, with which the author is clearly less familiar. Such a course would have avoided undermining the confidence of organists by the statements that the stopped diapason is virtually obsolete (page 44), and that the gemshorn is a stopped pipe (page 52). Again, the description of the violin, viola and 'cello as belonging to the viol family betrays an unfamiliarity with the history of these instruments. One wonders, too, in what sense the equally-tempered scale contains 120 discrete tones (page 76).

The succeeding chapters, on electronic tone formation and control, show the author in a much more favourable light. Not only does he cover a wide range of methods—electro-mechanical, photoelectric and purely electrical

—but he also discusses (with a frankness unusual in this subject) the inherent defects and limitations of each. Such errors as there are—for example, the incorrectly-drawn condenser in Fig. 144—are obviously mere slips of the pen. Although primarily dealing with principles, this section has a lavish provision of useful diagrams and circuits. It is a pity that the author makes no reference to the work of H. LeCaine, who has published papers in the *Proceedings of the Acoustical Society of America*, although a Canadian by nationality. His touch-sensitive organ and the solo " electronic sackbut " involve matters of acoustic and æsthetic principle which should find a place in a book of this kind. A chapter on loudspeakers, in addition to dealing with the familiar moving-coil speaker in a vented cabinet, describes an electrostatic and a ribbon speaker but makes no mention of the Ionophone. A final chapter on fully-synthesised music, with electrical generation of both " noise " and musical tones aided by tape-recording and controlled either manually or by punched paper rolls, opens up new vistas which attract or horrify, according to temperament.

The book is provided with a bibliography and an index. It is a well-produced and worthy addition to the rather sparse literature of the subject.

The First One Hundred and Fifty Years. John Wiley and Sons, Inc., New York.

THIS book has been prepared to celebrate the completion of 150 years of publishing by the American firm, John Wiley and Sons. It is modestly described by the president of the company as " an informal history." More than a score of authors have contributed chapters dealing with the different categories of scientific and other books which the house of Wiley has produced since the beginning of last century. Many of those books have been made available over here by Chapman and Hall, Ltd., which for the past sixty years has been Wiley's representative in this country. There are several chapters in the volume which will be of particular interest to engineers ; they are the chapters dealing with the preparation and production of books on such matters as the strength of materials, metallurgy, mining, civil engineering, mechanical engineering, electrical engineering, aeronautics and industrial management.

The chapters which are devoted to the history of the company comment on the small amount of industrial activity in New York in the early 1800s ; nevertheless, it is recalled, there were " many craftsmen in the city." But the authors of these chapters have not omitted to place on record the fact that elsewhere in the U.S.A. and in Europe there were numerous signs of the encroaching industrial revolution, a revolution that was to transform the ways of life for millions of people. These " signs " were undoubtedly factors which inspired Charles Wiley and his successors to devote attention to technical works in addition to those that catered for purely literary taste.

But the book contains something more than history. Throughout it, there is emphasis on the importance of the technical literature of the present. In connection with his company's celebrations, the reigning president, Mr. Bradford Wiley, has appropriately pointed out that to-day at least 75 per cent of the world's scientific literature is printed in English. This, he says, accounts for the importance of collaboration between British and American publishers in the production of books in all branches of modern science as part of the developments which are now taking place in technological education.

Handbook for Welding Design : Vol. I. Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 45s.

THIS is the first of three volumes compiled under the auspices of a special committee of the Institute of Welding, and it supersedes the Institute's " Handbook for Welding Structural Steelwork." It is intended to provide the designer of an assembly or structure to be fabricated in mild or low-alloy steels by are welding with the fundamental data required to design a product which is economical to make and of the stipulated quality. Wherever possible, it is stated, the information given in the book is based upon the relevant British Standard or other recognised specification. Where no such authoritative requirements exist the best British practice is quoted. The book is divided into eight main sections each of which was prepared by a sub-committee of members of the Institute. These sections deal with : the general principles of the metal-arc process ; choice of materials ; properties of sections ; classification of electrodes ; types of welded joints in mild and low-alloy steels ; design of welds ; typical assemblies ; and factors influencing welding costs. This new handbook provides a valuable source of reference for designers who will await with interest the publication of the companion volumes. The second volume will give typical worked and descriptive examples of the design for welding of products from different branches of the engineering industry ; the third volume will be devoted to the design of structures.

A Mathematical Tool-Kit for Engineers. H. A. WEBB, M.A., and D. G. ASHWELL, M.A., Ph.D., A.M.I.C.E., Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 10s.

FOR engineers who wish to study mathematics there exists an abundance of books : for the more numerous engineers who merely wish to use mathematics there is now at least one book. The techniques discussed principally concern integration, the first chapter dealing with some elementary differential equations and the last with Bessel functions, but included are expositions of Fourier series and the calculus of variations. The treatment is at all times distinguished by a very minimum of words, and the slender appearance of the booklet is therefore misleading. The authors say " Though we expect our arguments to convince the reader, we have not sought mathematical rigour " and their expectation almost invariably is fulfilled. A large part of the text is occupied by worked examples, and problems, conjoined with answers, are set. By the standards of an engineer, wishing for the most useful information with the minimum bulk and cost, this work stands high.

Books Received

Mechanics. By H. Weiler. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 25s.

Practical R.F. Heating for the Wood Industry. By J. Pound. Heywood and Co., Ltd., Ingersoll House, 9, Kingsway, London, W.C.2. Price 30s.

The Physics of Electrical Contacts. By F. Llewellyn Jones. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 35s.

Engineering Uses in Rubber. By A. T. McPherson and A. Klemin. Chapman and Hall, Ltd., 37, Essex Street, Strand, London, W.C.2. Price 100s.

Statistical Methods in Research and Production. Third edition. By O. L. Davies. Oliver and Boyd, 39A, Welbeck Street, London, W.1. Price 45s.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

METHODS OF TESTING PLASTICS

No. 2782 : 1956, Part 1. Price 10s. This standard (prepared in collaboration with the British Plastics Federation) introduces the first part of what will become a series of test methods used by the plastics industry for assessing the quality of its products.

Part 1 contains a group of test methods of use in assessing the effect of temperature on plastics and associated products. Tests are included for crushing strength after heating, deformation in bend under load at elevated temperatures, melting point, cold bend temperature, shrinkage and after-shrinkage, loss in weight on heating.

The complete series will include tests for application to moulding and extrusion compounds, synthetic resins and their solutions, semi-fabricated products such as sheet, thin film, rod and tube, and finished articles in the form of mouldings and extrusions. The series will incorporate many of the methods prescribed in existing British Standards for testing plastics materials. When preparing future editions attempts will be made to unify allied methods which differ only in arbitrary matters, so that a single method of test will be applicable to a much wider range of materials than at present.

POWER-DRIVEN RAIL-MOUNTED TOWER CRANES

No. 2799 : 1956. Price 7s. 6d. This is one of the series of specifications applying to cranes of different kinds, the object of which is to ensure that the cranes embody such fundamental principles of design as are essential to secure reliability and safety in operation. The standard applies to power-driven cranes of the tower type when mounted on rail wheels, whether the travelling motion is power-driven or not, and whether or not the jib can be derricked. It is the first British Standard for cranes issued since the publication of B.S. 2573, " Report on Permissible Stresses in Crane Structures," and the methods of calculating forces and the allowable working stresses in steel members in the crane structure are based on the recommendations of the report. Detailed requirements are specified for the design of the crane structure and hoisting equipment, brakes, electric motors, controllers and protective gear are dealt with, and requirements are specified for the performance testing of completed cranes.

The appendices include a list of British Standards for materials and equipment suitable for use in the manufacture of a crane, a list of Acts, Regulations and Orders affecting cranes in the United Kingdom, and notes concerning the track upon which a crane travels.

ELECTRICAL EQUIPMENT OF MACHINE TOOLS

No. 2771 : 1956. Price 5s. This new standard deals with control apparatus, motors, wiring and related accessories supplied as part of the machine tool and originating at its isolating switch. It specifies the conditions under which the equipment is applied on machine tools and it is intended to ensure the safety of personnel and adequate length of service from the electrical equipment. B.S. 2771 was prepared with the co-operation of representatives of the Machine Tool Trades Association. In this standard existing requirements directly affecting machine tools have been brought together as far as possible. During its preparation a close check was kept on overseas regulations so as to minimise the differences between it and such documents as " Machine Tool Electrical Standards, 1953," prepared by the National Machine Tool Builders' Association, and " Electrical Standards for Industrial Equipment, 1953," prepared by the Joint Industry Conference.

STEEL BOILERS (SOLID FUEL-FIRED) AND STERILISING PLANT FOR MILK UTENSILS FOR USE ON FARMS

No. 2809 : 1956. Price 5s. Part 1 of this new standard specifies requirements for solid fuel-fired steel boilers for use on farms and designed for supplying steam for sterilising milk utensils at a working pressure of not more than 15 lb per square inch gauge. The standard is intended to assist the manufacturer without unnecessarily restricting progressive design, and to safeguard the purchaser by ensuring that equipment will give reliable performance and be accepted for insurance. Provision is not made for flash steam boilers of the heat storage type. Part 2 specifies requirements for (*a*) sterilising chests for use with an independent boiler and designed for sterilising milk utensils at atmospheric pressure ; and (*b*) steaming tools for use during the sterilisation of milk cans. The foreword emphasises that the sterilising chest is designed to operate at atmospheric pressure and that it is essential, for safe operation for the vent to be maintained unrestricted.

Instruments, Electronics and Automation

No. 1

An exhibition of instruments, electronics and automation was opened at Olympia on Tuesday last and will close on Friday, May 17. It is clear from a tour of this exhibition that British firms are well able to develop methods of measurement and servo control which can expedite industrial production, particularly by economising in the expenditure of labour. It is equally clear, however, that many British industries, especially some involving smaller firms, make insufficient use of existing experience in instrumentation. Some exhibits at Olympia are described below.

MULLARD, LTD.

ON one of the two stands occupied by Mullard, Ltd., Torrington Place, London, W.C.1, there is an electronically controlled automatic machine designed to save time in drilling, marking out, plotting, draughting and spotting operations, on any kind of sheet metal. It is known as the

Fig. 1—The "Autoplot," an electronically-controlled co-ordinate positioning machine for drilling, marking out and plotting operations on sheet metals—Mullard

"Autoplot" and is believed to be the first fully engineered equipment of its kind in Europe. As illustrated in Fig. 1, it consists, briefly, of a work table, tool carriage and gantry, and an operator's desk, below which is an enclosure housing the electronic control circuits.

The gantry has a longitudinal travel of 30in, the tool carriage a transverse travel of 20in. The *x* and *y* co-ordinate datum lines can be set electronically anywhere within this 30in by 20in working area. Having established the datum lines, the tool head can be moved automatically into any required position merely by setting the required *x* and *y* co-ordinates on the dials and switching on the drive motor. As the leadscrews move the tool head over the workpiece each 0·001in increment of movement causes a pulse to be delivered to electronic counter circuits. The carriage continues to travel until the readings on the counter tubes agree with the dial settings. When the correct position is reached the tool is lowered automatically to the workpiece by a push button. Provision is made for manual control of the tool head movement, to override any preselected dial settings. Positioning is stated to be accurate to within 0·001in over any 6in of travel, and to within 0·002in over the whole work table. Final checking for accuracy of position is accomplished simply by selecting zero on each co-ordinate to return the tool head to the datum point. An automatic electro-magnetic gearbox provides two speeds of travel : a high speed of 60in per minute for the initial movement, and a reduced speed of 1·2in per minute for the final few thousandths of an inch.

The working surface of the table is 40in by 27in. Limit switches prevent the toolholder from overrunning, and a slipping clutch prevents damage to the tool by obstructions in the working area.

The "Autoplot" can also be used as a measuring instrument, the amount of travel of the head between two points being given by readings from the electronic counters. It has interesting possibilities in the drawing-office, particularly in the marking out of drawings of individual components. For example, a drawing showing the positions of a large number of holes can be simplified merely by marking out the hole centres with the "Autoplot" and compiling a running-out table which gives all the dimensional information as a list of co-ordinates, thus obviating the need for dimension lines. By using punched card or tape control it is possible to dispense with the marked-up drawing.

The Mullard display also includes an "L188" particle counter which is designed for the accurate counting and sizing of particles between 0·2mm and 0·64mm diameter, and has a wide field of application in the processing of paints, fuel oils and emulsions and in biochemical and nucleonic work. It is an improved production version of the prototype equipment which was shown last year at the British Instrument Industries Exhibition in London. The improvements include an ultrasonic mercury delay line instead of the nickel delay line hitherto used in the "memory" system, which ensures that no particle can appear twice in the final count. Because its bandwidth is wider the mercury line provides a delayed signal of greater fidelity. In addition, counting accuracy has been further enhanced by arranging each frame to be scanned several times, the successive counts being totalled in an electronic register and the average figure presented on the dekatron counter tubes. Another improvement is the inclusion of an alternative lens in a turret mount to provide for supplementary counting at a higher magnification, and thus give greater discrimination when size ranges lie very close together. Finally, the panel containing the display tube and counter units has been repositioned in the main rack to allow for operation of the equipment from a seated position.

Variable delay lines of high accuracy (with either manual or servo controls), such as those used in the particle counter described above, have many other laboratory uses. For example, they may be used to simulate radar signals or to simulate the effects of aircraft flutter ; in the development of television receiver circuits ; and in development work on pulse systems and servo systems.

An ultrasonic variable-delay line recently introduced by Mullard, Ltd., is to be seen on the company's main stand. It is available either as a basic unit which can be used independently or built into other equipment, or as a complete instrument with "Velodyne" control, input and output amplifiers, and power supplies. Mercury is employed as the delay medium. The signal to be delayed is applied to a quartz crystal transducer which converts it into ultrasonic energy. After travelling through the delay medium the ultrasonic energy is reconverted by a second transducer into electrical energy. The relatively low velocity of acoustic waves permits a much wider range of delay times than is conveniently attainable with electrical techniques. The sending and receiving crystals are mounted side by side and transmission of energy through the line from one to the other is effected via a corner reflector. This reflector is mounted on a sliding piston, the position of which governs the amount of delay. The piston is driven by a leadscrew, whose pitch is such that one revolution of the screw corresponds to a delay change of 10 microseconds. A dial and revolution counter are fitted which give an absolute calibration in delay time at a given temperature. Temperature coefficient of delay is −0·03 per cent per deg. Cent., and because of its large thermal capacity and high conductivity it is easy to control the temperature of the mercury line to very fine limits if very high accuracy is wanted.

The basic equipment is the "YL1200" delay line, which is intended for manual or automatic control and gives a direct reading of delay times. It has the following characteristics : delay range continuously variable from 25 to 330 microseconds, backlash equivalent to 0·01 microsecond, bandwidth 8 microseconds about the band centre at 15 microseconds, the frequency characteristic being level over this range to within 3 dB, insertion loss 50 dB between 390 ohm terminations, with Butterworth networks, spurious echoes 35 dB down. The complete equipment is enclosed in a rectangular casing measuring about 14½in by 2in by 1½in.

The "L287" equipment, which is also exhibited, is a self-contained laboratory instrument consisting of the variable delay line "YL2100," input and output amplifiers, "Velodyne" motor and amplifier, and power supplies. The "Velodyne" unit can be controlled by either an external or internal voltage source ; alternatively, manual operation is possible, the drive motor being engaged or disengaged with the piston by a magnetic clutch. Whether manually or servo operated, direct readings of delay times are given. The delay line is housed in a thermostatically controlled enclosure. Both input and output amplifiers match to 75 ohms and there is provision for r.f. and video inputs. The insertion loss of the entire equipment is zero.

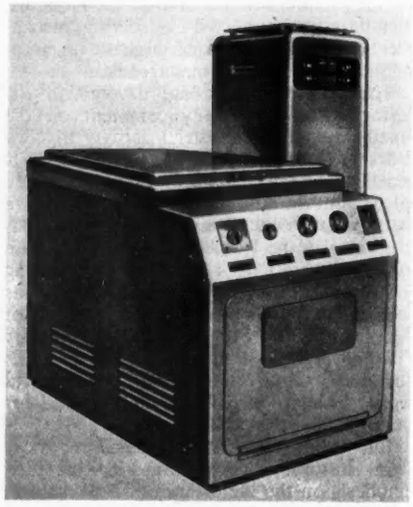


Fig. 2—Dawson low-frequency ultrasonic cleaning and degreasing machine—Mullard

The maximum rate of change of delay when the "Velodyne" drive is used is 3 microseconds per second, and control voltage is 3·3V per microsecond per second The L.287 instrument measures 19in wide by 10½in high by 20½in deep. The equipment is supplied in a two-tone grey metal case suitable for bench mounting. With the cover removed the front panel and cast aluminium chassis will fit into a standard 19in rack mounting.

A new system of low-frequency ultrasonic cleaning using large-area magnetostrictive transducers developed by Mullard Ltd., is embodied in cleaning equipment (Fig. 2), made by Dawson Brothers, Ltd., Leeds. This system is designed for operation with aqueous solvents, which can be used at high temperatures, and it is specially intended for the cleaning of objects contaminated by tenacious film. The scrubbing effect is produced by cavitation—an effect which is particularly marked at low untrasonic frequencies.

This principle is embodied in a small cabinet machine, which incorporates a Mullard 2kW low-frequency generator (type "E7696") operating at a frequency of 20 kc/s. It has a transducer of 360 square inches and a tank measuring 30in by 27in wide by 15in deep. It is complete with a continuously circulating pump drawing the liquid from the tank, passing it through fine filters and returning it to the tank in a clean state. The temperature is accurately maintained at the maximum figure and controlled by a thermostat. The inside of the tank is lined with "Epikote" to give a clean interior finish and to protect the tank against the action of any cleaning liquids which may be applied.

Elliott Brothers (London), Ltd.

Integrated systems for the control of large industrial processes provide the main theme on the stand of Elliott Brothers (London), Ltd., London, S.E.13. The display covers the full instrumentation of a nuclear power station, a typical graphic panel for an oil refinery platforming plant, instrumentation for the rubber and plastics industries, multi-channel remote indication and control equipment, including a v.h.f. radio link and a new version of the Elliott general-purpose analogue computer. This computer is shown simulating a typical closed-loop servo system—a "Metadyne" control system for turning a shaft in a heavy machine—including the introduction of backlash and its effect on response to step input functions. New non-linear computing units demonstrated include an electronic delay unit, a logarithmic multiplier, and an arbitrary function generator.

A demonstration is being given of the "Elliottel" data transmission system as applied to the remote indication of a liquid level and its recording on a Bristol's "Dynamaster" potentiometer instrument. The "Elliottel" system, which is based on the Elliott Shotter variable current transformer for converting the angular position of a rotating shaft into an electrical signal, can also be used to transmit data on pressure flow and other variables. The "Dynamaster" recorder can accommodate up to six separate channels of information.

Short Brothers and Harland, Ltd.

An analogue computer is also being shown by Short Brothers and Harland, Ltd., Belfast. An exclusive characteristic of this equipment is that it provides for continuous correction for "drift" in both repetitive and single-shot problems. A modification on the circuit of the standard linear amplifier limits the residual drift to less than 50 microvolts in a normal working day. At the same time the phase shift is restricted to a few minutes of arc. These refinements are important to operators who may be interested in the use of the computer for long-duration simulation in real time.

More than forty short electronic analogue computers are in service with various users at home and overseas in studies of aircraft stability and "flutter" (Fig. 3), the trajectories of guided missiles, the performance of a control system for a stripper gas/debutaniser gas plant, nuclear reactor control systems and power transmission systems.

Another exhibit on this stand is a new two-axis servo-controlled rocking table, designed by the company for development work on gyro-control systems and for their functional testing. Angular rotation of the table about each axis is controlled by electrical signals, either from an outside source, such as the Short analogue computer, or from a built-in oscillator. The rocking table is built as a single console, mounted on castors, and can be operated from normal electricity supply. The work table itself measures 16in by 10in and is mounted at a height of 46in from floor level. Quick-release panels are provided to facilitate inspection and maintenance. All electronic units plug into the framework and therefore no wiring need be disturbed when a unit is removed.

Fig. 3—Three Short computers in service with Vickers Armstrongs (Supermarine) Ltd. They are used for investigation of aircraft flutter and stability problems—Short Brothers

The company is also exhibiting a selection of electro-hydraulic servo-mechanisms, now under development and a range of high-pressure hydraulic components designed for industrial requirements; these components can be used for hydraulic systems in any form of automatic control.

Metropolitan-Vickers Electrical Company, Ltd.

An electronic digital computer, known as the "Metrovick 950," will be shown by Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17. This equipment, which we described in our issue of March 22, 1957, page 456, is designed for use in solving various mathematical, scientific and engineering problems and is the commercial version of an equipment that was developed, in the company's electronics department, for internal use.

The "950" computer works in the binary notation and consists of five main parts—input equipment, store, arithmetical circuits, output equipment and control panel. Information is fed into the machine by means of a photo-electric punched paper-tape reader, the paper tape having a five-hole code; the instructions and data are stored in a drum coated with a magnetic oxide, on which information is recorded in the form of magnetised spots on circumferential tracks. The arithmetical circuits performing the calculations consist mainly of transistors. The output unit punches holes in paper tape under the control of the computer, and this information can subsequently be read or printed out on a teleprinter. The operator or programmer co-ordinates the whole machine, using the control panel, in such a way that instructions are obeyed correctly and in the right order. The overall dimensions of the computer are 14ft 6½in by 4ft 10in by 6ft 1½in.

Another exhibit is the new "Magistor" photo transistor relay which is operated by the interruption of a beam of light, as described in our issue of April 12, 1957, page 579.

The equipment consists of two small units, a lamp box and a receiver. The lamp box contains a transformer supplying a prefocused lamp, whose light passes through a lens to produce a parallel beam. This light is directed on to the receiver unit, where it is focused by a lens on to the photo-transistor. The output of the photo-transistor energises a flux-resetting transductor, which controls a relay having changeover contacts. The relay operates when the light beam is broken. The photo-transistor is a germanium-junction transistor, which is light-sensitive and has the advantages of small size (¼in diameter by ¼in long), high sensitivity, low-voltage operation, robustness and reliability. The flux-resetting transductor is simply a choke wound on a core of special material, whose impedance can be varied by the action of the applied voltage during the reverse half-cycle; thus, it responds to applied signals in approximately one one-hundredth of a second on a 50 c/s supply. The circuit is so arranged that the transductor has very high impedance when light falls on the photo-transistor and a very low impedance when the light beam is interrupted. The transductor is connected in series with the relay coil across an external supply and acts like a magnetic switch, closing the circuit and energising the relay whenever the light beam is cut off. The "Magistor" photo-transistor relay can also be supplied with electrical counters for speeds of up to 10 per second. Batching counters are available to deal with at any predetermined quantity. Typical applications include counting, level control, edge position control and smoke detection.

The company is also showing its "MS6L" mass spectrometer, in the form of a simple portable equipment arranged specifically for leak detection. It uses the ability of the mass spectrometer to detect extremely small concentrations of one gas in another; in addition to high sensitivity it gives a direct measure of concentration and is therefore positive in indication. The mass spectrometer can be used for the testing of pressurised or evacuated systems; it will test for the presence or absence of leaks, measure the rate of leakage, and if necessary find the exact location of a leak. With vacuum systems the instrument is connected to the system, and the tracer gas is applied to the exterior, either by probing or by placing an envelope or hood around the whole or part of the system. Pressure vessels and systems are tested by placing the tracer gas inside under pressure, and sampling the atmosphere around suspected parts.

The "MS6L" mass spectrometer is a self-

contained equipment. The lower half of the cubicle contains the analyser tube, together with its associated magnet and vacuum system. The tube is a 90 deg., 10cm radius tube of all-metal construction and provision is made for easy dismantling of the ion source for cleaning or filament replacement. All switches and adjustments that are used during operation of the instrument are mounted on the sloping panel at the front of the drawer containing the electronic circuits. The sensitivity is better than 1 in 200,000 parts for helium in air. For leaks in vacuum systems this gives a minimum detectable leak of the order of 5×10^{-2} lusec (litres at 10^{-3}mm Hg per second). Such a leak rate means that only one-thirtieth of a cubic centimetre (at atmospheric pressure) would pass through in a year. With a system pressurised with helium at 15 lb per square inch a leakage less than 10^{-4} cubic centimetres per second should be detected. Vessels which can withstand larger pressure differentials may, with advantage, use higher pressure or, alternatively, economise in the use of helium by mixing it with air.

Lancashire Dynamo Electronic Products, Ltd.

A new instrument for detecting untoward increases in smoke density installations such as boiler house flues is being shown by Lancashire Dynamo Electronic Products, Ltd., Rugeley, Staffs. The installation (Fig. 5), consists of a light projector and photoelectric receiving unit, which are mounted on opposite sides of the stack or flue. Both these units are of cast iron, weatherproof construction, and are arranged for flange mounting. Easy access can be obtained to the internal optical components and provision is made for connecting a compressed air line, whereby the lenses can be kept clear of soot if stack conditions make this necessary. The light receiver can be equipped with a solenoid operated shutter, remotely operated from the control position, such that conditions of smoke may be simulated and the alarm operation checked. To guard against fluctuations in the light output of the projector lamp arrangements are made to regulate the r.m.s. current in such a way that it is maintained to very close limits, a ±1 per cent change for supply voltage variations of between $+10$ per cent and -15 per cent. The main control unit includes a meter which is calibrated in optical density ; it can be readily related to Ringelmann units for each installation. The alarm can be arranged to operate anywhere within the working range of the equipment, and suitable contacts are provided to operate a bell or klaxon in addition to the alarm recorder unit, which can be obtained as an optional extra. It is also possible to obtain a circular chart recorder which will give record of alarm conditions on a twenty-four-hour basis. Alternatively, installations can be provided to give a continuous smoke density recording.

An electronic adjustable speed system for fractional horsepower drives (Fig. 4) can also be seen on this stand. This equipment is designed to provide stepless adjustable speed of a small fractional horsepower (1/20 h.p. or less) d.c. motor. The equipment uses a single xenon-filled thyratron valve in a half-wave rectifier circuit to supply the armature of the d.c. motor, the field being separately excited from an independent rectifier in the equipment. The system provides up to a 5 : 1 range of speed control with constant maximum torque characteristic over this range and can be used in certain instances for speed ranges of up to 10 : 1. A range of small motors is available and the unit is used in conjunction with a geared motor unit providing output shaft speeds variable between 12 and 60 r.p.m. The load/speed characteristic of the equipment is substantially flat over a 5 : 1 speed range and the stability of the equipment against mains voltage fluctuations is good.

Fig. 5—Smoke indicator and alarm unit—Lancashire Dynamo Electronic Products

The unit can be provided in several forms, but in its basic design is suitable for bench mounting and for connection to the supply via a normal 13A three-pin plug and socket with fuse protection.

Kelvin and Hughes (Industrial), Ltd.

A new range of electronic controllers embodying transistors is being shown by Kelvin and Hughes (Industrial), Ltd., 2, Caxton Street, London, S.W.1. In this design of controller the measuring element is a sensitive moving-coil microammeter and the control section uses transistors. The instrument can be applied to any process where the variable to be measured and controlled can be converted into millivolt output, but the principal application is, in conjunction with a thermocouple or resistance thermometer, for measurement and control of temperature. It is stated to have a control sensitivity better than 0·1 per cent of full-scale deflection and a calibrated accuracy within 1 per cent of full-scale deflection.

In the measuring system the offset moving coil has a high torque/weight ratio and is magnetically suspended to minimise the effects of shock and maintain accuracy. A dual locking and coil shunt arrangement prevents damage to the movement during storage and transit. Zero adjustments can be made by a screw on the front bezel.

When used with a resistance thermometer for temperature measurement, a separate stabilised power supply is supplied. Copper and cold junction compensation is provided, automatically, for change in coil resistance with change in ambient temperature (copper error) ; and for cold junction temperature in the case of base metal thermocouples. There is also an external, readily adjustable, compensating thermocouple lead resistance (maximum 18 ohms).

In the control system a red pointer carried on a radial arm indicates control " set " point ; very fine settings can be made on the large calibrated indicator scale by a direct action drive from the external setting knob to this arm, which is concentric with the measuring pointer. The arm carries a light source having a prefocus lamp operated at far below full rating, and focused on to a photo-transistor by a spherical mirror. A vane, attached to the measuring pointer, passes freely between mirror and photo-transistor. Below " set " point, the photo-transistor receives full illumination of the light source, energising a relay to operate a switch to the " make " position. When the " set " temperature is attained, the vane obscures the light source to the photo-transistor, the relay is de-energised and the switch operates to the " break " position. As the vane passes the " set " point, it continues to obscure the light source until it reaches a stop ; therefore it enables true indication of temperature to be given up to 20 per cent of full-scale deflection above " set " point.

In the proportional control system the red control setting pointer is mounted on a separate radial arm, and the control arm carrying the light source, mirror and photo-transistor is made to oscillate relatively to the setting arm by means of a synchronous motor and an eccentric ring drive. The position of the eccentric is governed by friction only, and the external setting knob moves the control arm with respect to the setting arm : thus the amplitude of oscillation—that is, the proportional bandwidth—can be adjusted from zero to 10 per cent of full scale. The movement of a red-tipped pointer over a small subsidiary scale shows this oscillation. The subsidiary scale is graduated in percentage of full scale, and has a small index pointer which can be adjusted manually to correct for proportional offset.

A broken-thermocouple device is fitted as standard and, in the event of failure of base metal thermocouples, it causes the controller to close down the plant being regulated. For similar protection where rare metal thermocouples are used, a special compensated unit is available.

Although this instrument has an 8in length of calibrated indicator scale, it requires less than 46 square inches panel space. The die case light alloy case normally is finished black stove enamel, but other finishes may be obtained on application. The automatic locating plug-in chassis is standard and, on processes which can be interrupted only for very short periods, this facility for instant replacement is useful.

The company is also demonstrating its new system of automatic ultrasonic testing whereby precise ultrasonic testing can be carried out at high speed by automatic methods. The equipment shown consists of the automatic weld testing of pressure vessels. The mechanical traverse carrying the probes and irrigation system is arranged to inspect a weld by transmitting sound pulses and receiving the reflections. The sequence of events is displayed as a trace on a cathode-ray tube and/or recorded electrically on paper. The results can be compared with an X-ray photograph of the weld being examined.

(*To be continued*)

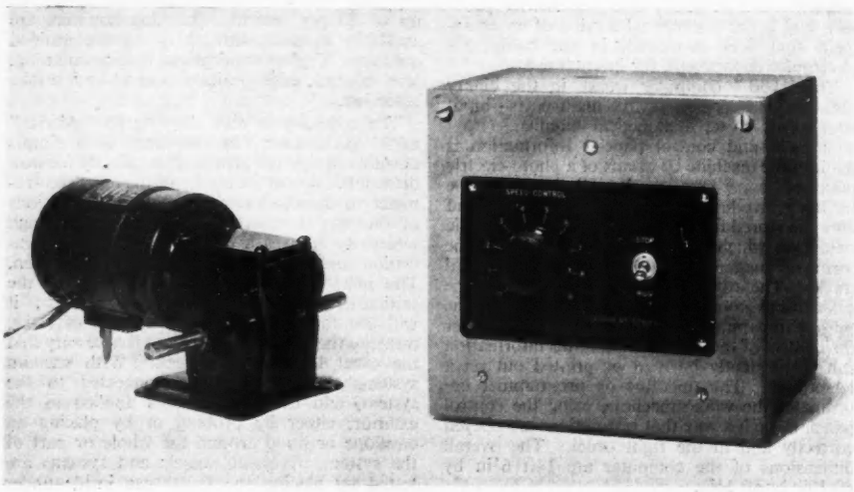
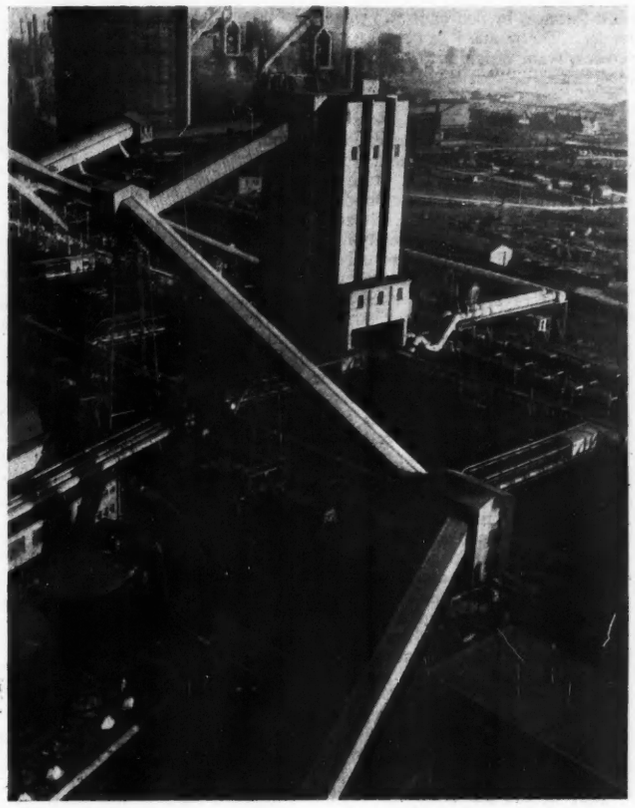


Fig. 4—Fractional h.p. electronic variable speed drive suitable for motors smaller than 1/20 h.p.—Lancashire Dynamo Electronic Products

Steel Works Coking Plant in Middlesbrough

A coking plant installed at South Bank, Middlesbrough, to provide metallurgical coke for the new Clay Lane blast-furnaces of Dorman Long (Steel), Ltd., is stated to be the largest single unit of its kind in this country. It comprises 150 ovens with a weekly throughput of 25,000 tons of coal, together with a complete coal and coke handling equipment and by-product plant. The installation is designed for duplication at some future date, and for this purpose the coal handling plant can be extended where necessary to double its present 310 tons per hour capacity to serve a second coke oven battery. Part of the coal handling plant to the service bunker can be seen in this illustration, with the coke handling plant to the blast-furnaces in the background.



PARTICULARS have been received from Simon-Carves, Ltd., of the new coking plant the firm has built at South Bank, Middlesbrough, to provide metallurgical coke to the Clay Lane blast-furnaces of Dorman Long (Steel), Ltd. The coal handling plant of the installation, which at present has a capacity of 310 tons per hour, is designed for extension to serve a second coke-oven battery in the future. At this plant, coal is discharged by Strachan and Henshaw rotary wagon tipplers through grids into track hoppers feeding a belt to the primary crusher house, where coal over 1in is screened out and crushed to 80 to 90 per cent below 1in. If required, the screen and crusher can be by-passed, and the coal delivered directly to a stocking-out conveyor, which is 1000ft between centres. This conveyor can discharge either over the end to a belt feeding blending bunkers, or through travelling trippers to a 100,000-ton stocking ground, over which the coal is distributed and reclaimed by bulldozer.

Coal blending is carried out in fifteen bunkers arranged in two rows and fed by two shuttle belts. These bunkers have a capacity of 5000 tons and one is reserved for non-coking coal, which is blended into the coking coal to improve the shatter index of the coke. Coal is discharged from the blending bunkers by rotary feed tables and conveyed to a 50-ton surge bunker, provision being made for oiling the coal while on the conveyor. It is then fed to hammer mills for reduction to 80 per cent below $\frac{1}{8}$in, after which it passes by way of a paddle mixer on to a series of belts to the service bunker.

The 5000-ton service bunker is centrally placed between two batteries of seventy-five ovens and is divided into halves, each with six sets of discharge doors. It is filled by an automatic traversing reversible shuttle belt arranged to give uniform distribution over a rectangular area. The hydraulically-operated bunker discharge doors are interlocked so that the six sets for each oven battery are operated in sequence, and they are electrically interlocked with the charger cars, so that the cars cannot be moved while the doors are open.

The twin-flue compound underjet ovens are arranged for heating by coke oven or blast-furnace gas, and are divided into two batteries of seventy-five, each draughted by a 280ft chimney. For ease of eventual rebuilding, each battery is subdivided into five blocks of fifteen ovens by intermediate buttresses.

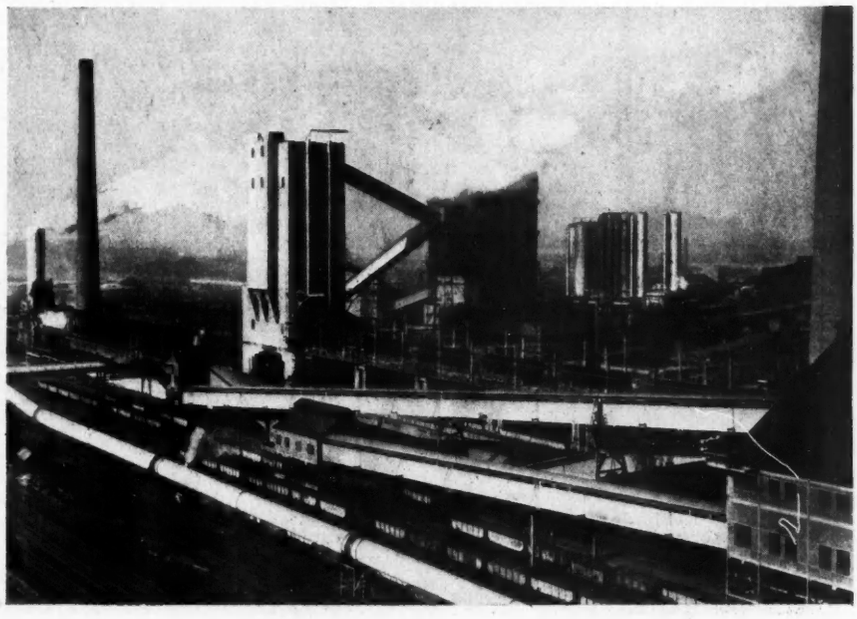
The leading oven particulars are as follows :—

Length over sole	44ft 7in
Chamber height	14ft 9½in
Mean chamber width...	1ft 5½in
Taper	2½in
Weight per charge	19·26 tons wet
Gross coking time	19·2 hours approx.
Throughput of 150 ovens	25,000 tons per week wet

In these ovens all the regulating points are readily accessible, and the fireclay used in the lower part of the regenerators allows the dividing walls to be grouted while at work. The waste gas flues support the side platforms independently of the buckstays and the ovens have single ascension pipes on the ram side, with liquor-sealed butterfly valves.

The oven heating system follows Simon-Carves standard practice, with rich and lean gas mains in the basement. There are four reversing winches, two operating thirty ovens each and two forty-five each. Two sets of oven machines are d.c. operated and an electromagnetic interlock fitted to the ram and the coke guides prevents a ram from operating until its guide is correctly positioned.

A quenching station at the chimney end of each seventy-five-oven battery is fitted with automatic quenching valves, and the hoods are baffled to arrest steam-borne grit. From a coke wharf 500ft long (which is illustrated overleaf) the coke is conveyed at 160 tons per hour to the primary screen house, from which plus 2in and 2in to 1½in coke is transferred either to the



Coke ovens and by-product plant at South Bank, Middlesbrough

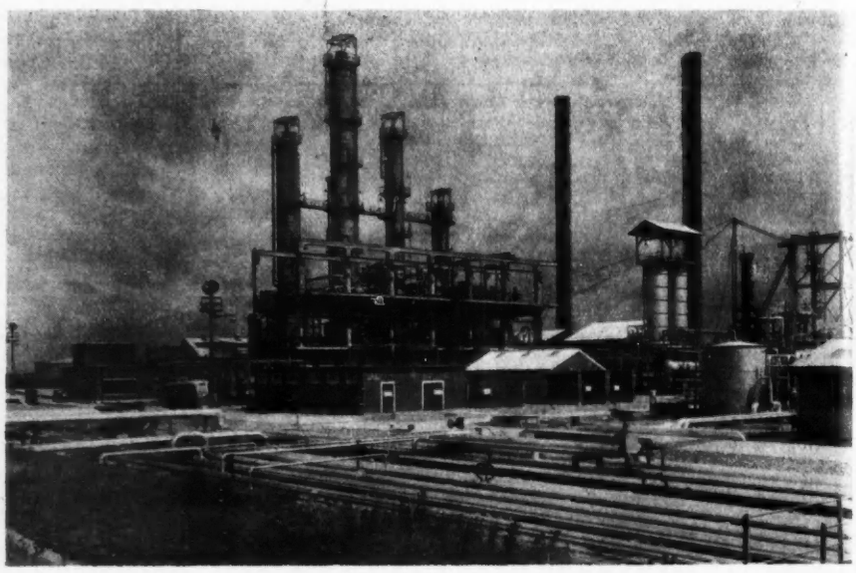
blast-furnaces by belt or to rail wagons by boom loader. The minus 1½in coke goes to secondary screens, from which road or rail wagons can be loaded with debreezed coke in a range of sizes.

By-Product Plant

The by-product plant handles the gas from the whole of the coal throughput and is arranged for duplication to serve a future oven battery. It is of orthodox design and embodies the indirect ammonia recovery system. Two foul gas mains, one from each battery of seventy-five ovens, take the gas to primary condensers, each main having its own mechanical tar catch tank where primary tar and liquor separation takes place and from which the circulating liquor supply is drawn. The two foul gas mains unite in a common inlet to nine primary condensers which cool the gas to 25 deg. to 30 deg. Cent. at the exhauster inlets. Two turbine-driven exhausters have a designed pressure differential of 100in w.g. and superheat the gas by 5 deg. to 10 deg. Cent. The gas passes to secondary condensers and thence through electro-detarrers to a three-stage naphthalene scrubber tower. The naphthalene is stripped from the wash oil and returned to the tar, the oil being cooled and pumped back to the scrubber. The gas then goes to two-stage ammonia scrubber towers with counter-current circulation of cooled liquor from the sulphate plant. Strong liquor from the first stage is pumped to the stills in the sulphate plant; free ammonia only is recovered, and full use is made of heat exchange between incoming liquor and outgoing still effluent.

Benzole is recovered by three tower scrubbers in series, using creosote oil which is stripped in the crude benzole still. The gas is finally freed of naphthalene in three static washers in parallel.

Part of the gas from the final naphthalene scrubbers is returned to heat the ovens, part is boosted into a main to the Warrenby steel plant, and the rest delivered to the Cleveland steel works by a low-pressure main. From a 5,000,000 cubic feet waterless holder at the blast-furnace plant an 84in main goes to the oven battery, where it divides into two 60in mains passing into the oven basement. The 45in rich gas main from the final naphthalene washers is connected to the 3,000,000 cubic feet holder and has connections taken from it to the following:—Via boosters to the steel works high-pressure main; through two 22in mains to the two oven batteries; through one 10in main to the steam superheater; through one 45in main to the gas bleeder, and through one 24in main to the sinter plant. Beyond the sinter plant connection the 45in main continues as a 42in main to the steel works.

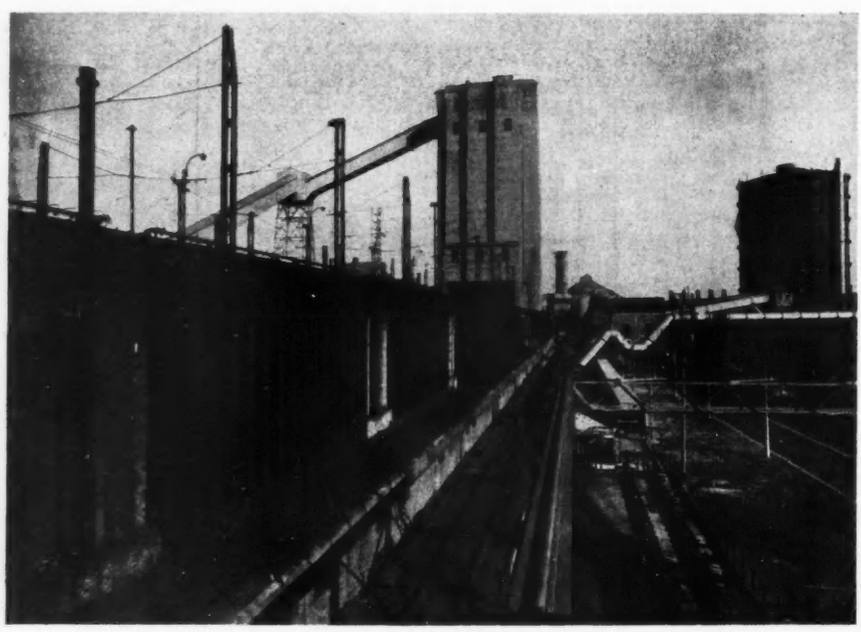


Platformer showing fractionating equipment, heaters and clay towers

Developments at Stanlow Refinery

Stanlow refinery, of the Shell Petroleum Company, Ltd., has expanded from a storage installation, which was established in 1922, to a completely integrated unit occupying two-thirds of an overall area of 1660 acres. The refinery, which has an intake of 15,000 tons of crude oil per day, has a balanced production including 60,000 tons of petroleum derived chemicals per annum.

THE oil refinery at Stanlow is about 9 miles to the south-east of Liverpool and bounded on the north by the Manchester Ship Canal. Since 1922, when a small storage installation was erected to act as a redistribution centre for finished products brought from overseas refineries, there has been continuous expansion. This expansion has been flexible in concept and has been adjusted from time to time in conformity with the policy adopted by the company to satisfy the changing demands occasioned by technical and commercial developments. The total area now owned by the Shell Petroleum Company, Ltd., is 1660 acres, of which two-thirds has now been developed to form a refinery which is complete and which has also achieved refinery balance. The latter is a complex problem which must take into account not only to-day's requirements but to-morrow's in the matter of supply and demand. To-day, Stanlow is an integrated refinery capable of producing a large number of widely different products, ranging from chemical solvents to bitumen, from imported crude oil, and capable of being adapted to meet additional requirements. The refinery has a daily intake of about 15,000 tons of crude oil and other feed stock, requiring the constant employment of some sixty oil tankers, and the chemical plants have an annual production of approximately 60,000 tons of petroleum-derived chemicals. Additional plant constructed and incorporated into the production pattern of the refinery includes a platformer, elemental sulphur and sulphuric acid plants, and ethane and ethylene unit, a plant to produce isopentane, an "Epikote" resin production unit, an additional waste heat boiler for the catalytic cracker, and a hydro-desulphurisation plant which was described in THE ENGINEER of June 17, 1955. Site improvements have also been made, including the straightening of the River Gowy, resulting in it being shortened by about 1000ft and enabling the company to reclaim about 11 acres of land.



Coke oven battery on coke wharf side with blast-furnace gas mains to ovens on the right

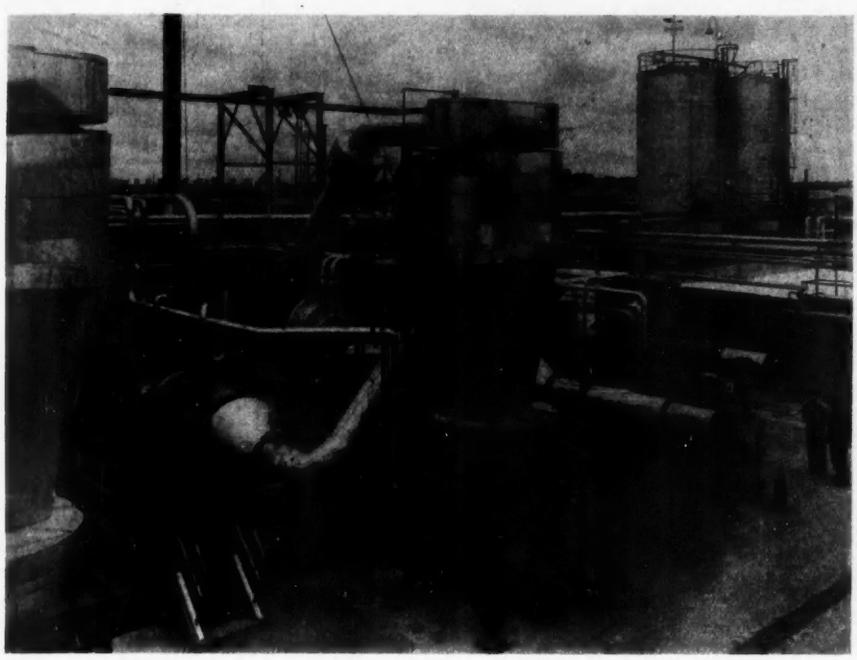
An important unit in the refinery expansion programme is the "platformer" (illustrated above), which catalytically reforms feedstock and produces valuable components for blending into high octane spirit. Carefully selected feedstock consisting of light naphtha from Venezuela, Colombia and Borneo crudes is used in the plant, which consists of three sections, namely, feed preparation, reaction and stabilisation. Immediately before use the feedstock is purified by fractionation on the refinery site. Furthermore, the feedstock is freed from traces of metal contaminants. These precautions are essential in order to ensure that the catalyst, of which there is about 25,000 lb in the reactors, has a long life, since it is in the form of small pellets of platinum supported on alumina.

In the process, which is endothermic so that the naphtha has to be heated between stages, the naphtha feedstock plus some hydrogen is heated in an oil-fired furnace to about 500 deg. Cent., at which temperature it enters the first of a series of reactors. The reaction pressure varies between

300 lb and 500 lb per square inch, depending upon quality, and after passing through the reactors and intermediate heaters the product enters a condenser and a high-pressure separator from which the hydrogen formed in the reaction is recycled and the platformate is forwarded to process for use in high-grade aviation gasoline.

An annual production of 13,000 tons was the basis upon which the elemental sulphur plant was designed, but subsequent improvements and modifications have raised this amount to 20,000 tons. The sulphur is produced in a Claus kiln in which hydrogen sulphide is burnt with about one-third of the theoretical amount of air and gives as products water and elemental sulphur. The plant is of Shell design, incorporating a patent burner for the hydrogen sulphide. The gas produced by burning the hydrogen sulphide passes through a waste heat boiler to raise steam and then through two Claus kilns arranged in series. In this arrangement the gas, after leaving the waste heat boiler, enters a cooler, where its temperature is lowered to 300 deg. Fah. and a certain amount of sulphur is recovered and then passes through a reheater to the first Claus kiln. Here the gas temperature is about 536 deg. Fah. and a quantity of sulphur is recovered and then the cycle of cooler and reheater is repeated before the gas enters the second kiln where the gas temperature is about 482 deg. Fah. Further amounts of sulphur are recovered at both cooler and kiln. Both kilns are filled with a form of aluminium oxide to act as a catalyst and designed for low space velocity and high conversion, the sulphur being separated by cooling and the use of cyclones. The effluent is burnt in an afterburner, together with air and a quantity of oil fuel, and the waste gases which are free from hydrogen sulphide are vented to atmosphere. Our illustration shows part of the sulphur recovery unit. In addition to disposing of the sulphur in solid form, it can also be delivered as a liquid in road tankers in which it is maintained at a temperature of 130 deg. Cent.

Among the unwanted products of lubricating oil refining and the manufacture of chemical solvents and resins are acid tars and sludges. These by-products used to be burned in a special boiler, but increasing production of lubricating oils has correspondingly increased the quantity of sludge and with it the need for a different and improved method of disposal. This is now carried out in a decomposer which has been designed and built by Cyanamide Products, Ltd., so that the refinery is now able to contribute to the reduction of atmospheric pollution while at the same time recovering sulphuric acid from the sludge at a rate of about 60 tons of acid for every 100 tons of sludge treated.



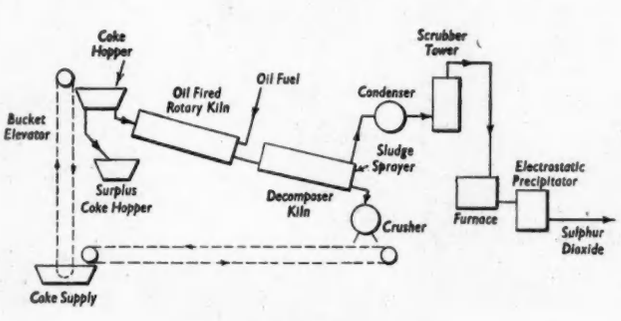
Sulphur recovery unit, showing cyclone separators with condensers, preheaters and catalyst beds in the background

The principal stages in the process are indicated in the accompanying flow chart. From the main supply, coke is raised by bucket elevator to a hopper from which it is fed into an oil-fired rotary kiln where it is raised to a temperature of the order of 800 deg. Cent. before it enters the decomposer kiln. Here the sludge is sprayed on to the hot coke, setting up a reaction which is endothermic, and the coke leaves the kiln at an approximate temperature of 250 deg. Cent., and then passes through a crusher before being fed to a belt conveyor for transfer to the main coke supply. The coke produced is light, friable and granular in character and of about $\frac{1}{8}$in particle size, and that quantity produced surplus to requirements is sold. From the reaction in the decomposer kiln is produced sulphur dioxide, water and hydrocarbons which enter a scrubber and cooler where the hydrocarbons are removed together with some of the water. After passing through a scrubbing tower and a furnace the gases enter an electrostatic precipitator which removes the entrained water while the scrubbed and dried sulphur dioxide which remains can be piped to the sulphuric acid plant.

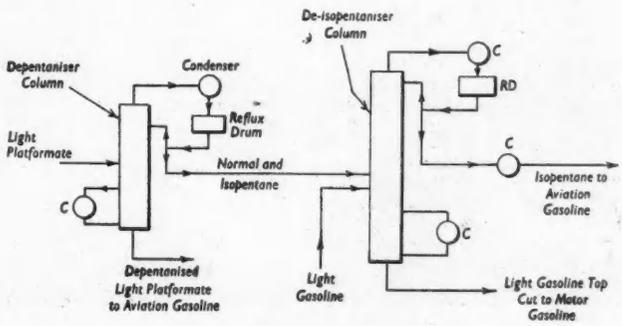
Sulphuric acid is produced in a conventional plant (illustrated on the next page) which burns hydrogen sulphide and elemental sulphur to produce sulphur dioxide, to which is added sulphur dioxide from the decomposer. The sulphur dioxide gas is cooled in a waste heat boiler before being treated in a scrubbing tower, after which it enters an electrostatic precipitator where the entrained water is removed. At the next stage the sulphur dioxide stream enters a drying tower, where it is dried by use of 93 per cent sulphuric acid, and is then heated in an heat exchanger before entering the four-stage converter, containing vanadium pentoxide as a catalyst, where it is converted to sulphur trioxide. After passing through the exchanger, where it gives up heat to warm the incoming suphur dioxide, the sulphur trioxide is piped to an absorption tower containing 98 per cent sulphuric acid and is made into oleum. The unabsorbed sulphur trioxide proceeds to another tower into which 93 per cent sulphuric acid is pumped and leaves as 98 per cent sulphuric, having absorbed the sulphur trioxide.

Ethane and ethylene is produced in a plant which was originally engaged in making propylene and butylene by pyrolysis of straight run gas oil, but has been redesigned to perform its present duties although it continues to make a certain amount of propylene. The method adopted was that of the pyrolysis of propane at low pressure and high temperature, combined with a short residence time. The change over to present production entailed the renewal of the furnace tubes in high alloy steel and the modification of the fractioning system so as to separate the ethane and ethylene as individual streams. For separating the ethane the fractionating system now includes a demethaniser which operates at high pressure and a low temperature of about -100 deg. Cent. This latter is achieved by two-stage refrigeration in which propane is used in the first and ethylene in the second stages.

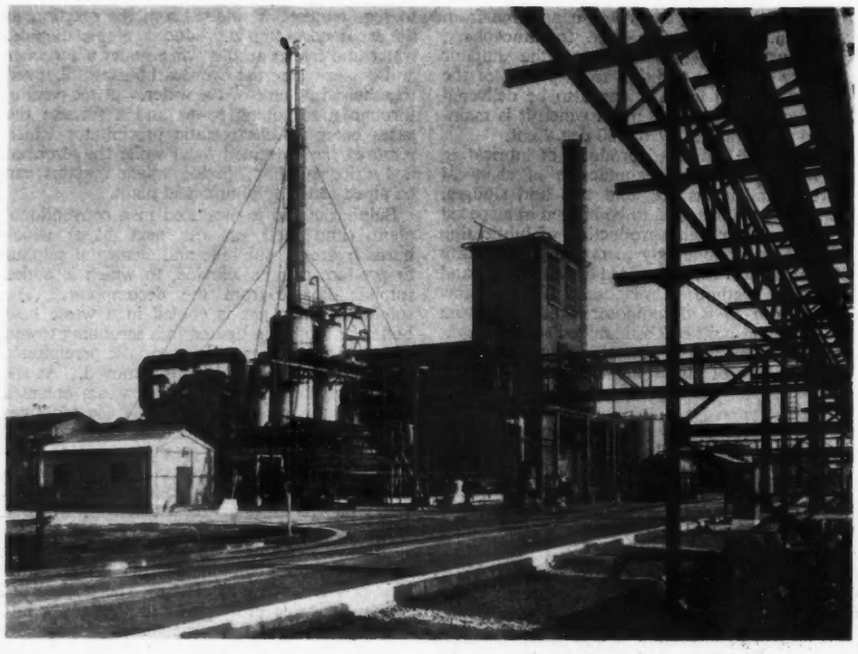
Another product of the Stanlow refinery is isopentane, which has good anti-knock properties and helps to control volatility of aviation gasoline. Two feedstocks are used, namely, light platformate and light gasoline from the crude distillation unit, and the final product contains not more than 3 per cent of normal pentane. Since the boiling points of isopentane and normal pentane are 27 deg. and 34 deg. Cent., respectively, a close degree fractionation is necessary. Our flow diagram shows that the light platformate is fed to a depentaniser column which is about 76in in diameter and 92ft high. The top cut gases of normal and isopentane pass through a condenser and a reflux drum before being fed to the deisopentaniser column, where they are joined by the other feedstock, light gasoline from the crude distillation unit. The column measures 114in in diameter and is about 200ft high, and is equipped with Shell Turbo-grid trays to give exact fractionation at



Flow chart of decomposer plant



Flow diagram of isopentane plant



General view of sulphuric acid plant and decomposer unit

high reflux. Again, the top cut products circulate through condenser and reflux drum before the isopentane is finally condensed and forwarded to storage ready to be added to aviation gasoline. Depentanised light platformate from the bottom of the depentaniser column is also added to aviation gasoline while the light gasoline top cut from the bottom of the deisopentaniser column is added to motor gasoline. A view of the plant is shown in the photograph which we reproduce.

The refinery is now equipped to produce "Epikote" resins, which are condensation polymers resulting from the development of chemicals by the petroleum industry and are produced synthetically from diphenylolpropane (DPP) and epichlorhydrin (ECH). The resulting epoxy resins are long chain polymers, which are either liquid or solid according to the length of the chain, and they possess toughness, flexibility, adhesion and resistance to chemicals and solvents, properties which they transfer to those formulations of which they may form the base.

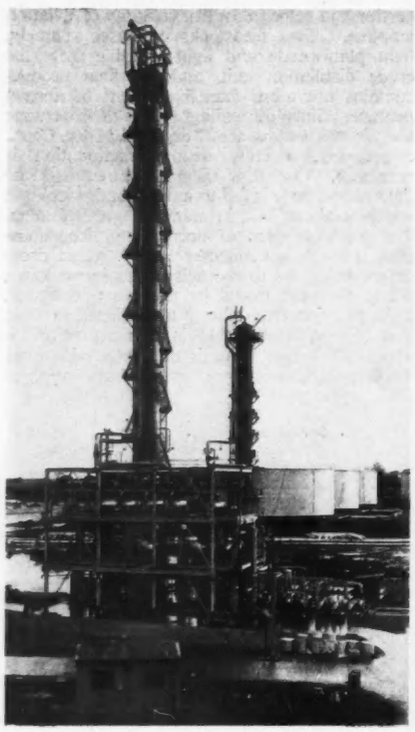
The catalytic cracking unit already incorporates in its system two waste heat boilers which produce steam for process purposes and to increase further the overall efficiency of the unit, another waste heat boiler has been constructed. This is a Thompson La Mont water-tube boiler having an M.C.R. of 210,000 lb per hour, a working pressure of 256 lb per square inch, and a final steam temperature of 680 deg. Fah. with a feed water supply at 220 deg. Fah. The boiler is designed to burn flue gases, from the top of the regenerator, in the presence of oil fuel, the former having a pressure of about 11 lb per square inch at the regenerator outlet, which is approximately 140ft above ground level. A duct of about 52in in diameter, which is designed on the basis of a three-pin arch and supported in a light steel rectangular tower, leads the waste gases from the top of the regenerator down to the boiler. The gases pass through a reducing valve to the boiler burner box and enter the furnace through an annulus surrounding a conventional oil fuel burner. Air is supplied to the pressurised combustion chamber by a Howden forced draught fan which is arranged for both turbine and electric drive and is rated to deliver 39,200 cubic feet per minute of air at 60 deg. Fah. against a pressure of 19in w.g.

Feed water is force circulated by two pumps, one turbine and one electrically driven, each having a delivery of 1,560,000 lb per hour at 322 lb per square inch. The feed water passes through the economiser, then the first and second evaporators and the water-cooled combustion chambers then through the superheater to the mains. There are two turbine-driven feed pumps, manufactured by the K.S.B. Manufacturing Company, Ltd., each able to deliver 248,000 lb per hour against a discharge pressure of 310 lb per square inch. There is a large amount of sensible heat in the flue gases and the carbon monoxide, amounting to approximately 7 per cent and having a calorific value of about 340 B.Th.U. per cubic foot, is burnt to carbon dioxide. The flue gases from the boiler are passed to atmosphere up a mild steel, self-supporting chimney 12ft in diameter by about 200ft in height.

The addition of new units forming the large expansion programme of the Stanlow refinery called for increased maintenance services so that the existing facilities proved to be inadequate. Various maintenance shops were located in different areas of the refinery, and to meet the new and expanding requirements a new building was designed and built to integrate all crafts under one roof. This building, of which we show an internal view, measures 200ft by 342ft, and is of four-bay construction having a reinforced concrete floor except that in the blacksmiths' section, which is of hardwood blocks. Heating is by space unit heaters working in a closed system and the ventilation system provides for two changes of air per hour generally, but with provision for augmented ventilation in the welding and auto repair shops. Fresh water, steam and compressed air services are provided, while oxygen, acetylene gas and hydrogen are supplied from a central source.

Fluorescent lighting is fitted and electric power for the workshops is provided from a substation fitted with two 500kVA transformers. For handling material, stores and maintenance jobs there are overhead travelling cranes of 5 tons capacity and other ancillary equipment, while the electricians', welding, blacksmiths', sheet metal, pipe fabrication, machine, fitting and other shops are fully equipped with modern machines and machine tools so that all maintenance requirements can be met. The importance of the part played by maintenance in the running of the refinery is illustrated by the fact that over 40,000 separate jobs are dealt with per annum, and 45 per cent of them are required to be completed within a working day.

In addition to the central workshop there is a central instrument workshop which has a floor area of 6777 square feet and is heated and ventilated so that there is established a slight outward flow of air, which is filtered, thus ensuring the minimum entry of dust.



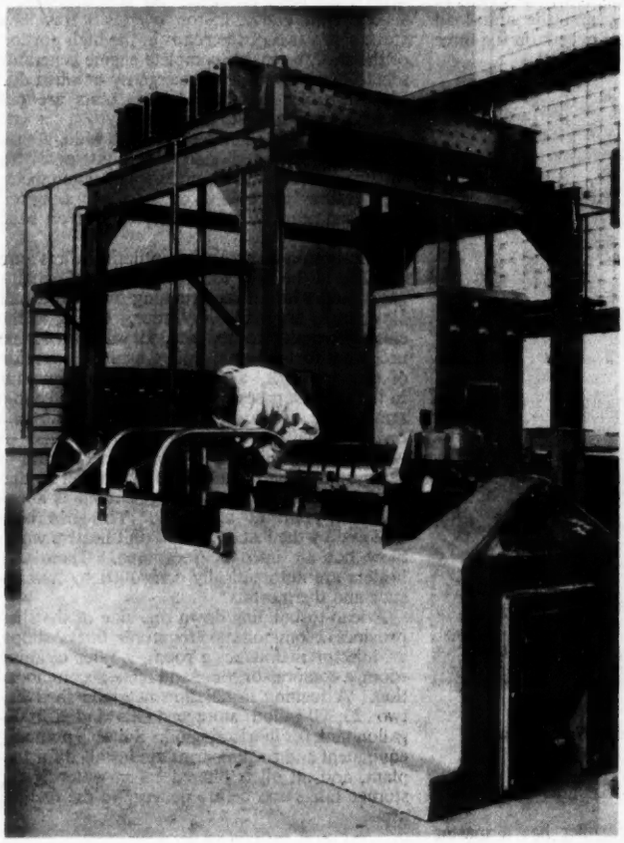
Isopentane plant

Machine shop, forming part of the central workshops

Safety in Mines Research Establishment Laboratory

FOR several years the Safety in Mines Research Establishment has been carrying out its work under difficulties owing to its branches being accommodated in widely separated and in some cases unsuitable and congested premises. These difficulties have now to some extent been relieved by the provision of a new laboratory specially designed and built to the particular requirements of the establishment. The first section of the laboratory, which is situated in Broad Lane, Sheffield, was opened last week by Lord Mills, the Minister of Power, and is occupied by several departments of the establishment.

The introduction of organised and continuous research to improve safety in the coal mines of this country can be traced to 1908 when the work was inaugurated by the Mining Association of Great Britain, and the late Dr. R. V. Wheeler was appointed to take charge of investigations.



20-ton pulsator used for fatigue tests on chain links, with 400-ton testing machine for testing pit arches at the rear

A year later the Home Office took over responsibility for the work, which was transferred to laboratories and explosion galleries at Eskmeals, on the coast of Cumberland. This experimental station was transferred to the Mines Department of the Board of Trade in 1920, and later the Safety in Mines Research Board became responsible for its work. In 1926 the field station south of Buxton was opened for large-scale investigations on explosions, explosives and other experiments. Two years later central laboratories were established in Portobello Street, Sheffield, where the staff had ready access to mining areas, and were in close proximity to the Applied Science Department of Sheffield University, with which a close relationship has always been maintained. Another close relationship was started with the Imperial College of Science, South Kensington, where researches on mine supports and on wire ropes were inaugurated.

The Safety in Mines Research Establishment, as it is now known, came into being under the Coal Nationalisation Act of 1946, when the Ministry of Fuel and Power assumed responsibility for research into safety and health in the mines. Since that time the scope of the work has steadily developed and the establishment now has a staff of nearly 400. Its work is broadly arranged under five main headings concerned with all aspects of explosion and fire research, engineering and metallurgical research, pneumoconiosis research, mathematical research and supporting services.

The new premises are L-shaped, one wing consisting of a large engineering testing laboratory, and the other wing of three stories providing accommodation for a number of smaller laboratories, offices, and a photographic department. The main engineering testing laboratory is a building about 100ft long by 40ft wide and 26ft high, the whole floor area being served by a 7½-ton overhead travelling crane. It is organised and well equipped with plant for investigations on wire ropes, mine supports, haulage gear and other mine equipment. A machine of particular interest to be installed in the near future is what is believed will be one of the largest wire rope testing equipments in the world. This machine will be capable of exerting loads up to 400 tons on 20ft lengths of rope and up to 200 tons on 175ft lengths. Initially it will be installed with a reduced bed length to handle ropes up to 25ft long. When the proposed second part of the new laboratory is built the foundations for this machine will be extended into the new foundations to the full length of 230ft to accommodate the complete 175ft capacity bed.

For the testing of pit arches and props there are two 100-ton compression rigs and the new 400-ton capacity machine to be seen in one of our illustrations. This machine has an upstroking table actuated by four hydraulic cylinders, one at each corner, and these cylinders can be operated together or in any required combination to impart eccentric loadings to simulate mine conditions. It accommodates work within an approximate area of 5ft by 15ft up to 8ft high, and is provided with supplementary table elements to cover various requirements. Other equipment installed includes pulsators, universal testing and various standard machines and rigs adapted to provide for the many demands on a laboratory of this kind.

The smaller individual laboratories arranged for special aspects of research cover an area of some 11,000 to 12,000 square feet. Metallurgical investigations, particularly those into the causes of deterioration of mining equipment leading to failure in service, faults in design and manufacture, provide much of the work in these laboratories. There is equipment for non-destructive testing techniques using ultrasonic, magnetic and radiological methods and projection microscopy, and much of this equipment has been specially developed or modified to suit particular classes of work. A recent report of the establishment deals in detail with work on the detection of weld flaws in chain links, and one of our illustrations shows an investigation in progress on the links of a cage suspension gear using gamma radiography.

For the variety of research work covered, many instruments and rigs and much prototype equipment have to be developed, and in this connection an instrument design section and a drawing and design department work in close collaboration with all sections of the laboratory. A statistical section, which has been in operation for some time, is also housed in the new building, and is providing a service of steadily increasing importance to supplement the research work on materials, processes, methods and equipment. There is also a technical presentation section which is engaged in the preparation of reports and other literature and which provides photographic facilities.

The sections of the establishment dealing with pneumoconiosis research, airborne dust research, statutory testing of apparatus, intrinsic safety research, mines gas analysis and breathing apparatus are still housed at the Portobello Street building of the establishment. They will be transferred to the new laboratory when the second stage of the building programme is completed.

Gamma-radiography of cage suspension gear. The operator can be seen placing film casettes behind the welds in chain link

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SHIPBUILDING STATISTICS.—The Shipbuilding Conference states that during the first quarter of 1957 British shipyards booked orders for ninety ships of 600,000 tons gross. These contracts bring the total orders for the twelve months ended on March 31 to 382 ships totalling 2,759,000 tons gross, and the total on order to 896 ships of 6,741,000 tons gross. Of the orders placed 43 per cent are for oil tankers, 43 per cent are cargo ships, and 8 per cent are passenger and passenger/cargo ships.

Diesel-Electric Trains for the Southern Region

WHEN the summer services are introduced on the Southern Region of British Railways next month, three of the steam train services on the Charing Cross to Hastings via Tunbridge Wells line during the business hours will be replaced by four diesel-electric train services in each direction. This will be the first stage in a programme, to be completed in June, 1958, for the replacement of steam-hauled trains by diesel-electric trains on this line. For this initial programme, ten six-coach vestibule corridor train sets are being provided. Each six-coach train will consist of two diesel-electric motor coaches with four corridor trailer coaches semi-permanently coupled together between them. These six-coach units have a driver's cab at the front of the motor coach at each end, and when required two of the units can be coupled together to form a twelve-coach train under the control of one driver. Each motor coach has a 500 h.p. diesel generator set, to give a total of 1000 h.p. for a six-coach or 2000 h.p. for a twelve-coach train. The trains are designed for a maximum speed of 75 m.p.h. and a balancing speed of 68 m.p.h. on level tangent track.

Multiple-unit diesel-electric trains in the new maintenance shed at St. Leonards (West Marina)

The new coaches are being built at the Ashford and Eastleigh works of the Southern Region. Their underframes are of the B.R. standard welded design, the first seven units being 56ft 11in over the headstocks and all subsequent units 63ft 5in over the headstocks. On the trailer coaches the single bolster bogies have inside swing hangers and are fitted with Hoffmann roller bearings. The bogies of the motor coaches are also fitted with roller bearings and the traction motors, which are in the trailing bogie of each coach, are similar to and interchangeable with those on the latest electric stock on the Region. The welded steel bodies of the coaches are of straight-sided design, as their width over the panels had to be restricted to 8ft 0¼in to comply with the loading gauge between Tunbridge Wells and Crowhurst, for which the 9ft width of the new standard rolling stock is too great.

Each motor coach incorporates a driver's cab, engine-room, guard's and luggage van, and a second-class passenger saloon. Three of the four trailer coaches in a six-coach train are second-class open coaches and the fourth a first-class corridor coach. An interesting point in these first-class compartments is the use of adjustable seats, which, when pushed back, give ease of access and when pulled out the required degree of comfort.

The power equipment in each motor coach consists of an English Electric "4 SRKT/II" pressure charged, four-cylinder diesel engine, giving 500 h.p. at 850 r.p.m. This engine is directly coupled to an English Electric six-pole generator of 330kW and an overhung auxiliary generator of 13·2kW. The main generator supplies two four-pole, nose-suspended, axle-hung traction motors connected in permanent parallel and mounted on the rear bogie of the coach. The auxiliary generator supplies low-tension circuits at 90V for lighting control gear and battery charging purposes. The main generator has a continuous rating of 600A at 550V, its output being regulated by an auto-load regulator, which also controls the traction motor field weakening. There are four engine speeds of 450, 620, 750, 850 r.p.m., and the auto-load regulator controls the engine output on the three higher speeds to 330, 420 and 500 b.h.p. approximately.

The driver's master controller has a master switch handle controlling movement and direction, and a main power handle. The master switch handle has four positions, off, forward, engine only and reverse, while the other handle has eight positions, off and seven power notches. A deadman's handle is operative when the master switch handle is in the forward or reverse positions.

The control equipment consists of electro-pneumatic and electromagnetic contactors and group switches. All of the power contactors and relays are carried in a single case suspended from the underframe. The remaining control gear is mounted in an auxiliary cupboard which forms a partition on the offside of the driver's cab.

The engine-room is a partitioned section between the driver's cab and the guard's compartment, and, in addition to the power equipment, also houses the oil and water coolers, fuel supply equipment, filters, &c. The radiator and its fan are enclosed at one end of the engine-room, and the fan is driven through a vertical shaft and a gearbox by an extension shaft from the oil engine. This radiator fan is designed to draw a constant stream of cooling air past the engine installation as well as through the radiator. An automatic fire-extinguishing equipment in the engine cab is arranged to shut down the diesel engine if an outbreak of fire occurs and at the same time gives audible and visual warning to the driver if he is in a remote driving position. Discharge of carbon dioxide gas from this equipment is automatic.

Each motor coach has suspended from its underframe between the bogies a Westinghouse compressor, air reservoirs and electro-pneumatic brake equipment, two 340-gallon fuel tanks which provide sufficient fuel for about 800 miles, and two battery boxes. The coaches are electrically heated and current is supplied for this purpose from the main generator, three coaches being fed from each power installation.

To provide maintenance facilities for the new trains the shed to be seen in the accompanying illustration has been built and equipped at St. Leonards. This shed, which is open at one end, is of steel and asbestos sheeting construction, with extensive glazing in the roof and sides to provide as much natural light as possible. It is 440ft long and 87ft wide, with an eaves height of 37ft for a length of 100ft from the closed end and 16ft elsewhere. There are four pitted roads 410ft long, each of which will accommodate a six-car unit, and a 25-ton overhead travelling crane spans two of the roads in the high portion of the shed, to enable complete engine generator sets to be changed in an emergency or when due for overhaul, so that the time units are out of service is reduced to a minimum.

The pits are 4ft 3in deep and 4ft wide, with a step 2ft 3in high each side to facilitate access to traction motors and underslung equipment. Pit lighting is provided by staggered tungsten lamp bulkhead fittings at 30ft centres on each side.

Push-button-controlled ventilating fans are installed in the roof for the removal of exhaust gases, and with all fans running two and a half air changes are made very hour. Owing to the close proximity to the sea, it was considered necessary to take precautions against corrosion of the steelwork, as the presence of sulphur in the exhaust gases, when mixed with the damp atmosphere, would condense as sulphuric acid on the steelwork with very serious results. It was, therefore, decided to provide a measure of background heating and insulate the roof so that the temperature of the steelwork remains above the dew point at all times. This has been achieved by the installation of unit heaters which blow hot air into the roof area. These unit heaters are automatically controlled by humidistats and thermostats.

A lean-to building down one side of the shed provides accommodation for stores, fitters' shops, an injector maintenance room, a filter cleaning room, a compressor room and office accommodation. A fuelling installation near the shed has two 23,500-gallon storage tanks and a 1000-gallon tank for lubricating oil. Suitable pumping equipment and fuelling arms are installed for this plant, and all oil is filtered before entering the storage tanks and before delivery to the fuelling arms.

HARD METAL-FACED MECHANICAL SEALS.—Crane Packing, Ltd., Slough, Bucks, is now making mechanical shaft seals with inserted hard metal opposing faces for applications where abrasive materials have to be handled. These seals are interchangeable with the firm's standard Types 1 and 2 seals with the usual metal/carbon faces. They are suitable for use with temperatures up to 100 deg. Cent., pressures up to 200 lb per square inch, and for shafts from ⅜in to 2½in diameter. The seals must be provided with adequate coolant, as they can generate up to 50 per cent more heat in service than the standard forms of seals.

POSITIVE AXLE LUBRICATION.—Positive oil circulation has now been standardised on the final reduction gears of all Leyland vehicles with a single worm drive axle. The rear end of the worm shaft carries a gear pump which takes in oil by a tube leading up from the sump in the differential housing; that part of the pipe which is outside the axle is removable to allow the final drive assembly to be removed. The pump delivery passes through drillings in the shaft end cover and another external pipe to two jets above the worm. Oil flung off the worm is led by gravity to the double-tape roller bearing behind, and the parallel roller bearing in front of, the worm.

Industrial and Labour Notes

Engineering and Shipbuilding Wages

The reports of the Courts of Inquiry into the engineering and shipbuilding wage disputes were published by H.M. Stationery Office at the end of last week. The membership of both courts was the same, namely, Professor D. T. Jack, Mr. C. J. Geddes and Brigadier L. C. Mandleberg, and the principal recommendations presented in the reports are, for the most part, identical. The courts' suggestion as to wage increases is that the parties should consider the alternatives of a rise of 8s. 6d. a week on the consolidated time rate for skilled workers, or 11s. a week with provisions for a wages "standstill period," the reduction of restrictive practices, and loss of working time, all of which should be embodied in a negotiated agreement.

The reports then suggest that consideration should be given to the setting up of national joint councils which would be competent to make periodic reviews of the engineering and shipbuilding industries. These councils would take into account such matters as changes in the cost of living, changes in productivity and changes in the economic prospects of the industries. The councils, the reports add, should concern themselves positively with the productive efficiency of the industries. In the report on the engineering industry a further suggestion is made that careful consideration should be given to the desirability of including in the agreed procedure for settling disputes a provision that unresolved disputes at district or national level should be referred to arbitration. Dealing with the general problem of wages and inflation, the reports re-emphasise a proposal made by courts of inquiry in 1954. This proposal relates to the setting up of an "authoritative and impartial body to examine and advise upon the wider problems of wages policy in an inflationary setting." With such a body, it is urged, the Treasury, the British Employers' Confederation, the Trades Union Congress and the nationalised industries should be associated.

The reports were discussed on Monday at the conference of the Amalgamated Engineering Union's national committee. As a result, a resolution was passed instructing the A.E.U. executive to propose to the Confederation of Shipbuilding and Engineering Unions the acceptance of the 11s. a week increase, though with "such modifications of the terms as can be obtained."

Railway Shopmen's Pay Claim

It was announced last week that a settlement had been reached in respect of a claim for a 10 per cent increase in the pay of railway workshop staff. At a meeting of the British Transport Commission and the employees' side of the Railway Shopmen's National Council, a 5 per cent increase was agreed upon, the effect of which will be to raise most rates of pay by from 7s. to 8s. 6d. a week. The agreement, which affects about 120,000 railway workshop staff, has been made retrospective to January 7 last.

The agreement incorporates proposals for periodic reviews by the British Transport Commission and the unions of wages and working conditions and other relevant matters, such as increased productivity. At last week's meeting, the employees' representatives said that they appreciated the British Transport Commission's position and were prepared to give "formal and serious consideration" to the proposals.

Industrial Investment

According to the Treasury's *Bulletin for Industry*, gross fixed investment by private manufacturing industry rose very steeply during 1955, but that advance slackened during 1956, although it accelerated again slightly during the fourth quarter. For last year, as a whole, the increase by value was 20 per cent compared with 27 per cent in 1955. Within the total, spending on building work rose the most last year, but much less quickly than in 1955.

The slower rise of fixed capital expenditure in 1956, it is stated, was common to most manufacturing industries, and spending by the textile and clothing industries was lower than in 1955. In the chemical and the iron and steel industries, however, expenditure last year rose faster than in 1955. The *Bulletin* goes on to say that the "investment intentions" of manufacturing industry indicate that expenditure as a whole this year will be about the same as in 1956. There will undoubtedly be further substantial increases in chemicals and iron and steel, but they are likely to be offset by falls in the metal-using industries and vehicles, textiles, food and paper and printing. Expenditure on building is expected to drop a little, but that on plant, machinery and vehicles is expected to show a slight rise.

About public investment, the *Bulletin* says that expenditure in 1956 by the National Coal Board, the Central Electricity Authority, the two Scottish Electricity Boards, the Gas Council, the British Transport Commission and the Airways Corporations is estimated to have been about £537 million, or £32,000,000 more than in 1955. This year, it is expected that the increase will be considerably more, and that the total will reach £643 million. Expenditure by the British Transport Commission shows the biggest increase within the total and, on account of the railway modernisation programme, is likely to be £43,000,000 higher this year than last. The increase in capital expenditure this year by the Central Electricity Authority is expected to be of the order of £24,000,000, giving an estimated total of £233 million.

Top Management

Last week-end, the British Institute of Management held its sixth Scottish conference at Gleneagles, the general theme of the discussions being "Top Management Planning and Control." Mr. H. P. Barker, who is the chairman of Parkinson and Cowan, Ltd., opened the conference, and in his address warned that great firms and great industries could be placed in danger of extinction if their eyes were not open wide enough. The day had gone by, Mr. Barker said, when massive industrial investment could be safely laid out on the "never-never" system of depreciation, which had done more than any one thing to eviscerate and weaken many of our great industries.

Mr. Barker went on to express his belief that full employment, both of workpeople and professional men, was "with us for ever." The needs of mankind for capital equipment, he said, were so powerful and in some directions so clearly seen that it was unimaginable that the needs and the men to fill them could ever be separated. He did not think that top management had even yet understood the significance of a permanent state of competition for brains. People, Mr Barker added, were the human capital of industry, and serious thought must be given to the problems which faced top management in creating working environments in which people would want to participate. If any management failed in that task, Mr. Barker commented, its "long-term extinction" was pretty likely. In order to ensure a flow of human capital into a business, Mr. Barker suggested, it was necessary that the top management should organise the human society it controlled in such a way that four separate climates were created for every employee from managing director to labourer. The first climate, he said, concerned security, the second justice, the third incentive, and the fourth personal recognition.

British Trade Fair at Helsinki

At a press conference in Helsinki, last week, Sir Norman Kipping, director-general of the Federation of British Industries, and Mr. W. P. N. Edwards, a director of British Overseas Fairs, Ltd., gave some details of the plans which are now being completed for the British Trade Fair and Exhibition to be held at Helsinki, from September 6 to 22, under the joint patronage of H.M. Queen Elizabeth and the President of Finland. This exhibition is being organised by the Federation of British Industries through its subsidiary, British Overseas Fairs, Ltd., in association with the Finnish-British Trade Association and the London Chamber of Commerce. More than 500 British manufacturers, in co-operation with their agents in Finland, will be exhibiting their products in Helsinki's exhibition building and on an adjoining open space.

The exhibits inside the hall will consist of machinery, tools, general engineering products, instruments, chemicals, textiles, office machinery and consumer goods. There is to be a special display of consumer goods of contemporary design selected by the Council of Industrial Design, and in the open space there will be representative displays of motor vehicles, agricultural machinery, contractors' plant and earth-moving equipment. To mark the occasion of the exhibition, the Finnish licensing authorities are making available import licences to the value of £1,000,000. A special "farm feature" will demonstrate the methods and equipment used by British farmers to-day to save time and labour, and will show how these can be adapted to the particular problems of the Finnish farmer. It will also include a display of land drainage machinery which should prove suitable for use under Finnish conditions.

It was stated at the conference that a programme of supporting events would give the Finnish people an opportunity of observing some of the traditional ceremonies associated with the British way of life and of sharing in some elements of Britain's cultural development. On the invitation of the Lord Mayor of Helsinki, the Lord Mayor of London will fly to Helsinki on September 5. He will travel in a forty-five-seat turbo-prop "Viscount" of British European Airways, accompanied by the Lady Mayoress and other civic dignitaries. Mr. Derek Walker-Smith, Minister of State, Board of Trade, Sir Hugh Beaver, president of the Federation of British Industries, and other representatives of industry will also attend the fair.

German Industries Fair, Hanover

No. II—(*Continued from page* 698, *May* 3)

British Exhibits

FOR the first time, the Board of Trade showed at the Hanover Industries Fair the development of atomic energy in Great Britain, and the applications of radioactive isotopes to various branches of industry. In Hall 3 there was a fine model of the Calder Hall power station, along with another model of the Dounreay fast reactor. In both models, ample use was made of neon tubes to illustrate the flow of gases and liquids. Films were also shown at intervals. In Hall 5, the Isotopes Division of Harwell had arranged a series of exhibits to illustrate the uses of radioactive isotopes in a range of industrial processes. On this stand was a model of the radiation laboratory, showing the equipment which has been designed at Harwell to study the effect of gamma rays on the structure of plastics and chemicals.

Also for the first time, the Birmingham Exchange and Engineering Centre, in collaboration with the Board of Trade, was in operation, in the Export Börse, to answer inquiries regarding the sources of supply of British engineering products whether exhibited at the Fair or not.

120-ton railway crane lifting a locomotive—Krupp-Ardelt

Fried. Krupp

On the enlarged stand of Fried. Krupp, already illustrated, an outstanding exhibit was a railway crane, one of two similar cranes designed and constructed for work in Australia by Krupp-Ardelt G.m.b.H., Wilhelmshaven. This crane is, we understand, the largest of its kind to be built in Europe. Our illustration shows it lifting a 60-ton Krupp tender locomotive; the large counterweights at the rear may be noted. The jib is equipped with two lifting hooks, the inner hook being designed to handle weights up to 120 tons at a radii up to 20ft, while the outer hook deals with smaller weights up to about 15 tons at distances up to 50ft. The weight of the crane is 134 metric tons and the axle loading about 22·5 metric tons. As shown at the Fair, the crane is equipped with a boiler and steam engine. The coal-fired boiler generates steam at a pressure of 170 lb per square inch absolute, and the engine has a designed output of 180 b.h.p. at 250 r.p.m. Westinghouse braking equipment is fitted throughout. If desired, the crane can be supplied with a complete diesel engine drive instead of the steam engine.

Brief mention may also be made of two interesting models shown on the Krupp stand, illustrating the progress recently made in the reduction and smelting of low-grade metallic ores. One showed the Krupp-Renn installation at Salzgitter-Watenstedt, which will shortly be completed and is to handle low-grade ore of 34 per cent iron content. The plant will produce 200,000 tons annually of ore with 94 per cent iron content. The other model showed a similar plant for the production of 50,000 tons per annum of nickel-steel alloy, from a low-grade nickel ore at Larymna in Greece.

Water turbine for 1200kW generator—Escher Wyss

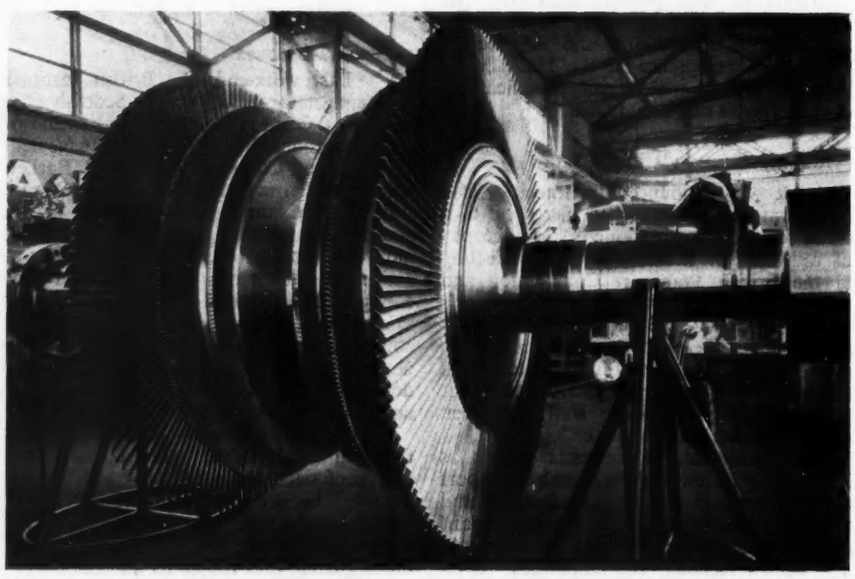
Escher Wyss G.m.b.H.

On the stand of Escher Wyss G.m.b.H., Ravensburg, in Hall 3, an outstanding exhibit was the large water turbine for the Reuttener Textilwerk A.G., of Reutte (Tyrol). Our illustration shows clearly the general character of the exhibit, which is about 20ft in height. A double-regulation, tunnel water turbine, it is designed to work under a head of 6m, and the range of speed is 165 to 1000 r.p.m. Output at the generator terminals is 1200kW. The ring for regulating the guide blades runs on rollers, and the levers controlling the position of the sixteen guide blades are clearly seen in our illustration. The ring is worked by two electric motors.

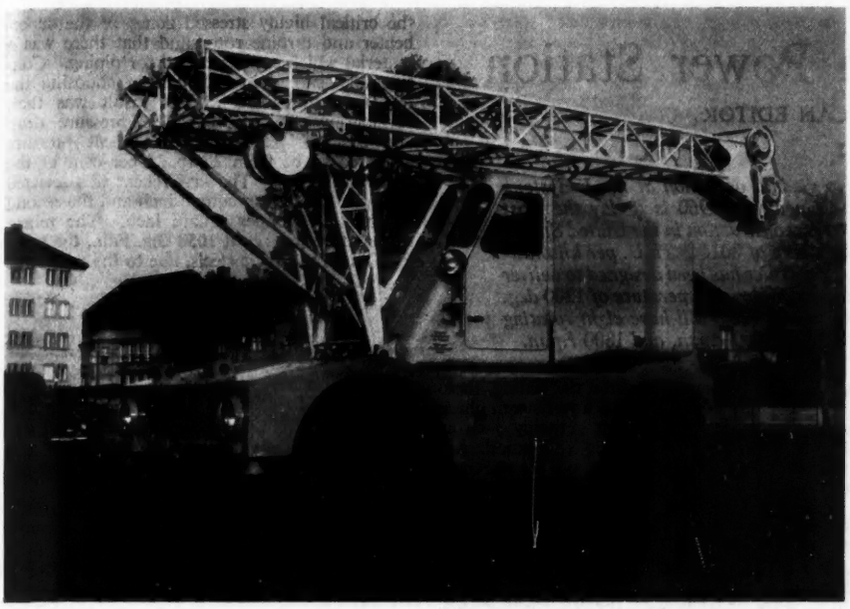
Escher Wyss also showed examples and models of variable-pitch marine propellers.

Maschinenfabrik Augsburg-Nurnberg A.G.

This year the M.A.N. Company showed on its main stand a number of exhibits connected with advances made in steam engineering. We have chosen for illustration the new 150MW M.A.N. steam turbine, which is stated to be the highest output to which a tandem compound construction has been applied in Europe. The triple-tandem unit operates at a speed of 3000 r.p.m.



Low-pressure turbine rotor of 150MW turbine—M.A.N.



10m jib stowed in position on the roof of the crane for transport—M.A.N.

and is designed for a live steam supply at a pressure of 185 atmospheres absolute (maximum 200 atmospheres), and a temperature of 525 deg. Cent. (maximum 540 deg. Cent.). The temperature of the circulating water is 21 deg. Cent. The steam passes in opposite directions through the high and intermediate pressure stages, so that only a lightly loaded thrust bearing is necessary between them, while the low-pressure stage is balanced owing to the double-flow design. The casings are specially designed to ensure symmetry of shape and transmission. Built-in diaphragm carriers form an inner shell, and the outer casing of the low-pressure stage is of welded construction, which effects a considerable reduction in weight.

The transfer of steam from the intermediate casing to the low-pressure casing is by means of four cross-over connections arranged at angles of 45 deg. Besides giving a weight reduction this arrangement offers better flow conditions, and enables the cross-over ducts to be enclosed inside the sheet metal casing, giving a compact and pleasing appearance. The low-pressure rotor which formed a prominent exhibit in Hall 3 is illustrated on page 734.

On the M.A.N. stand in the open-air section, a series of M.A.N. mobile cranes was shown. Above is seen one of these mobile cranes with the 10m jib folded down on the roof of the cab, so that when travelling the crane may comply with the road traffic regulations. The folded dimensions are : length, 6·2m ; height, including jib, 3·87m, and width about 2·50m. The collapsible jib can also be supplied with a special head, so that by fitting intermediate members it can be increased to a length of 30m for the construction of multi-storey buildings.

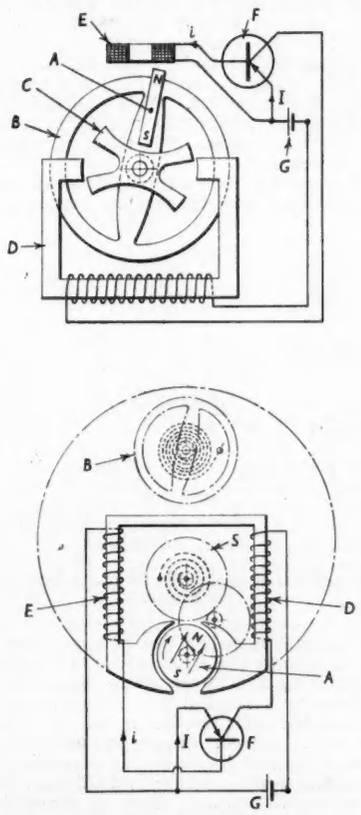
(*To be continued*)

Transistors in Watches

Modern miniature batteries, such as that of Mallory and Elgin, are capable of giving an output equivalent to that which the mainspring of a wrist watch develops in the course of several years (500 joule for a battery volume of 0·5 cubic centimetre). It was therefore an obvious step to seek a method of driving a small watch mechanism electrically by means of such a battery. Two solutions present themselves, namely, to arrange the balance wheel as an oscillating motor (and, consequently, omit the mainspring), or to have a normal watch mechanism, but with a shorter mainspring which is periodically rewound electrically. Such systems have been realised, but the wear of the moving electrical contacts required meant that their endurance was insufficient. A description of how this difficulty can be overcome was given in a lecture given in Paris on November 24, 1956, before the "Société Chronométrique de France."

According to the Lavet-Dietsch system, a transistor may be used in the place of mechanical contacts. Since a transistor contains no parts subject to wear or consumption, it lasts almost indefinitely.

Two schemes are illustrated below. The upper illustration shows a balance wheel arranged as a swing motor. The wheel *B* carries the small permanent magnet *A* and the soft iron armature *C*. When the latter is in its position of symmetry with respect to the field magnet *D*, the balance wheel moves at maximum speed. It is in this position that the magnet *A* passes a search coil *E* and in it induces a voltage causing a minute current *i*. This results in the transistor becoming conductive and allowing a much larger current *I* to flow through the power circuit, which comprises the battery *G*, the transistor *F* and field magnet *D*. In consequence, the armature *C* receives one impulse during each half-oscillation, sufficient to make up for frictional losses and to drive the watch hands through the usual gearing.



Balance movement with transistor (top) and rewinding mechanism (bottom)

The second arrangement (bottom illustration) has the advantage that a standard balance *B* and escapement mechanism can be used, i.e. components which have already been developed to a high degree of perfection. The mainspring *S* is rather shorter and less strong than normal, and is rewound periodically by a small electric motor comprising the rotor magnet *A*, about 4mm in diameter, acting through a train of gear wheels, and the field magnet *D*, which also carries the winding *E*, which plays a similar role to that of the search coil in the preceding design.

These designs (which are as yet in the experimental stage) are rendered feasible by the small size of the electrical components. The transistor has a diameter of approximately 3mm and a length of 5mm.

Frankfurt Battelle Institute

The 1956 annual report of the Frankfurt Battelle Institute has recently been published. The expansion of this institute, which is concerned with sponsored industrial research, has made further advances during the past year. At the end of December, the scientific staff numbered 371, compared with 160 in Geneva, and over 2600 at the Battelle Memorial Institute, the American parent organisation. Research contracts totalled DM.4·05 million (1955, DM.3·02 million), of which Germany accounted for 77·2 per cent, other European countries (including Great Britain) for 18·3 per cent, and overseas countries for 4·5 per cent. The largest sector was chemistry (22·3 per cent), followed by physics (20·6 per cent), and metallurgy (12·3 per cent). Pressure of work necessitated the setting up of a new department, including the fields of plastics, rubber and textiles, which had formerly come under the Department of Chemistry. The Construction and Works Department, which previously had purely a service function, has for the first time been engaged on outside orders for production and pilot plants. The report quotes many examples of actual work which the Institute has carried out and which range over the whole field of technical science. By the completion of a fourth building another 3690 square metres of floor space have been added, making a total of 19,520 square metres. The liaison agency of the Institute in Great Britain is Battelle Institute, Ltd., 24, Ryder Street, London, S.W.1.

German Handicrafts and Trade Fair

The ninth German Handicrafts and Trade Fair, which will be held in Munich from May 15 to 26, will have an increased foreign participation, as compared with last year. Of the twenty-five countries which will be exhibiting, the main participants will be Italy and the Scandinavian countries, which may be regarded as leading in modern design, while Eastern European and Oriental countries will be showing examples of traditional arts and crafts. Special exhibitions, within the framework of the Fair, will include "Furniture and the present trends in interior decoration," and "How does Europe live today ?" Information may be obtained from the organisers : Verein für Handwerks-Ausstellungen und Messen e.V., Munich 12, Theresienhöhe 14.

Swiss Pulpwood Consumption

Annual consumption of timber used for papermaking in Switzerland now runs at nearly 900,000 cubic metres, of which not quite one-half is homegrown. In 1955, 400,000 cubic metres came from the country's own forests, the remainder being imported from Finland, Sweden and Canada. The amount of wood used in the production of pulp has more than doubled within the last twenty years, and 1954 and 1955 increasing at the rate of 100,000 cubic metres per annum. The price index at the end of last year stood at 300 for the timber, while the index for paper was 190 (1939=100).

Eddystone Steam Power Station

BY OUR AMERICAN EDITOR

No. I

The 325MW super-pressure unit which is to go into operation at the Eddystone power station of the Philadelphia Electric Company in 1960 is to-day the most advanced steam-electric generating scheme under construction in the United States. It is hoped that the unit will achieve a net heat rate of 8016 B.Th.U. per kilowatt-hour and a 42·6 per cent thermal efficiency. The boiler has been designed to deliver steam at a pressure of 5000 lb per square inch gauge, at a temperature of 1200 deg. Fah. and at a rate of 2,000,000 lb per hour. The turbine will have eight rotating elements on two shafts, rotating respectively at 3600 r.p.m. and 1800 r.p.m.

THE design pressure of 5000 lb per square inch gauge of the Eddystone unit now being built by the Philadelphia Electric Company establishes a new high mark in the development of the steam plant cycle. The two curves which are reproduced in Figs. 1 and 2 show certain relationships not normally realised, but extremely important to a consideration of steam generators and turbines which are to operate in the supercritical pressure range. Fig. 1 shows the relationship between specific volume and temperature

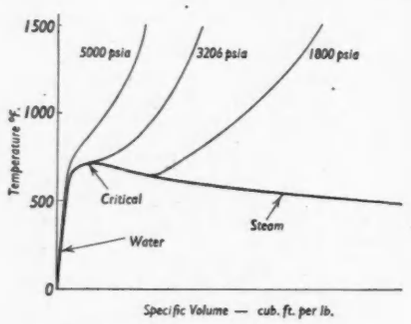


Fig. 1—Graph of relationship between specific volume and temperature

for water. The heavy line is the saturation temperature line and shows how the specific volume of saturation pressure water increases as the temperature increases and, similarly, how the specific volume of steam at saturation pressure decreases as the temperature increases and that at the critical pressure the specific volume for each is identical. In subcritical pressure steam generator design a differential in specific volume of water and steam has been depended upon to accomplish such results as to cause circulation in the boiler circuits ; to make possible the operation of water separators and scrubbers to produce steam purity and vapour-free water in the downcomer circuits ; to leave most of the dissolved solids behind in the water remaining in the steam generators after boiling, and to make effective a drum water level in the control of feed water and in the use of a water gauge glass. In supercritical pressure design other procedures or devices have had to be developed.

Fig. 2 shows the relation between temperature and enthalpy in the case of water. Again, the heavy line is the saturation line and the fine lines show the conditions for several pressures. In this case the phenomenon of latent heat at a subcritical pressure is shown by a constant temperature line drawn at an arbitrary level between the saturated water phase on the curve and the saturated steam phase on the curve. The 5000 lb per square inch line in the figure is of great interest in that it is always above the saturation line and has no horizontal section. This indicates a smooth transition from the liquid phase to the vapour phase and the complete absence of a latent heat zone. This figure illustrates the following facts, which, though present at more conventional steam conditions, are exaggerated and, therefore, of greater consequence in the supercritical state : (1) expansion from a supercritical pressure will result in a very substantial reduction in temperature ; (2) unless the initial temperature is almost as high as has, until recently, been considered the ceiling, there is a possibility of passing into a wet steam phase during expansion at constant enthalpy such as through a valve or a nozzle. This emphasises the need for high temperatures and for reheat in supercritical pressure turbines.

In 1954 an agreement was reached between Combustion Engineering, Incorporated, the Westinghouse Electric Corporation and the Philadelphia Electric Company to co-operate in the building of a supercritical pressure unit of 275MW capacity with throttle steam conditions of 5000 lb per square inch gauge and 1150 deg. Fah. and with two reheats to 1050 deg. Fah. each. It was further agreed that the design would contemplate operation with a throttle steam temperature of 1200 deg. Fah. and that this temperature would be actually attained after successful operation at the lower level. The power station is being built on a site at Eddystone, midway between Chester and Philadelphia, Pennsylvania.

In selecting the size, steam conditions and heat cycle for this unit, which is known as Eddystone No. 1, the criterion was to take maximum advantage of the most recent technological advances as far as they could be supported economically. It has been generally acknowledged that these very advanced steam conditions require large-capacity turbines if their full advantage is to be realised ; otherwise, the highest pressure blading is so small that by-passing is a significant quantity. This factor indicated a desirable minimum size of the order of 250MW to 300MW. On the other hand, the maximum satisfactory size for the generator had to be considered since the original concept comprised a tandem-compound 3600 r.p.m. set. With a supercharged rotor and stator, a generator of 275MW was felt to be entirely feasible. This, therefore, was the size decided upon.

An analysis of the improvements in efficiency to be obtained by increasing steam pressure, even

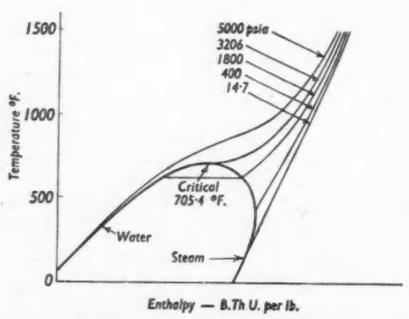


Fig. 2—Graph of relationship between enthalpy and temperature

at a temperature of 1200 deg. Fah., as shown in Fig. 3, indicates that there is little to be gained by exceeding 5000 lb per square inch, and the problems to be faced at this pressure appeared to be sufficient for the time being. Thus, this pressure was chosen. In regard to temperature, it was recognised that materials in normal use at this time were limited to about 1150 deg. Fah. in power station service. However, the opinion was expressed that materials were available which would permit a 1200 deg. Fah. design in the critical highly stressed zones of the superheater and turbine rotor and that there was a material which could be used for piping. Considerable care was exercised in choosing the reheat pressure zones. The result was that, considering efficiency, effect of pressure drop and cost of pipe, the best reheat pressure appeared to be from 20 to 25 per cent of the throttle pressure. The first reheat was selected at about 1150 lb per square inch and the second at about 275 lb per square inch. The reheat temperature was set at 1050 deg. Fah., the practical limit for ferritic steels, due to the very large

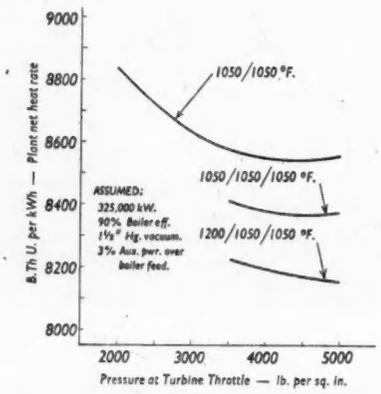


Fig. 3—Graph showing influence of steam pressure at turbine throttle on power station performance at various steam temperatures

reheat piping being too costly if made of austenitic material. Furthermore, it was felt that 1050 deg. Fah. was about as high a temperature as should be considered in the highly stressed large rotating spindles at the reheat-return points.

Almost immediately after the decision to proceed had been arrived at, it was realised that substantially better performance could be obtained by cross-compounding the set and using an 1800 r.p.m. low-pressure turbine with long blades and greatly increased exhaust areas. This also provided a possibility of reconsidering the capacity of the unit. A review of the situation indicated that a size of about 325MW would be appropriate, and a study of the costs indicated that the 50MW increment in capacity could be obtained at substantially less than the average cost. All these factors together led to the choice of a 325MW cross-compound turbo-generator and a steam generator with a design output of 2,000,000 lb of steam per hour.

In addition to the supercritical pressure, the very high temperature, the two reheats and the large last-stage 1800 r.p.m. blading, a great deal of attention has been directed to the other parts of the cycle in an attempt to capture all available heat units. To this end the pressure level of each feed water heater, the use of drain coolers and heater desuperheater zones, the position of heater drains and the disposition of pump and turbine shaft-seal drains, among many other items, have been studied carefully. The end result has been to produce a calculated heat rate at nominal rating of load and steam conditions and with 1in back pressure of 8016 B.Th.U. per net kWh.

The Steam Generator

The steam generating unit for the Eddystone power station is designed to deliver steam to the turbine at a pressure of 5000 lb per square inch gauge at a temperature of 1200 deg. Fah. and at a rate of 2,000,000 lb per hour. There are two stages of reheat, both at 1050 deg. Fah., and these steam conditions make this the most advanced thermal cycle ever undertaken in the United States. To design such a unit required a very careful evaluation of many important factors, such as the characteristics of water and steam at the extremely high pressures and temperatures, the materials available for use in superheaters and piping, and the control system which would be most suitable from the standpoint of operation and at the same time afford

maximum protection to the equipment. In accordance with the physical considerations outlined above, there is no point throughout the length of a heated circuit in a supercritical pressure boiler where water and steam can exist as a mixture. Designs which depend on the separation of water from steam in a drum for recirculation through the evaporative circuits are therefore not applicable. The only suitable selection is a forced-circulation design of the once-through type. For the same reason it is impossible to concentrate impurities which enter with the feed water by partial evaporation in a boiler drum and then remove them from the system through a blow-down system. Not only does this require a revised approach to the question of feed water purification but it also affects the operating procedures and the design of the control system.

The so-called once-through boilers are not a new development. There have been many designs developed and operated during the past twenty-five to thirty years—a few in the United States but most of them in Europe. The greatest single deterrent to their general use has been the lack of adequate means for water purification. The knowledge gained in the past few years through research and experience has changed that situation to the extent that the American boiler construction industry is now ready to adopt principles which will achieve reliable operation at supercritical pressures. Some years ago, in thinking ahead to the day when units designed to operate at pressures above the critical would become a reality, the management of Combustion Engineering, Incorporated, became convinced that one of the most essential items would be a control system which could be integrated carefully with the design of the steam generating equipment. An extensive series of surveys of designs operating in Europe, which took place over a period of years, indicated that the principles employed by Sulzer Brothers, of Switzerland, were best suited to American needs. Not only did this organisation have the extensive background of experience in the successful operation of once-through steam generating units, but it also had developed a control system which could be adapted readily to the supercritical pressure cycle.

While there has been nothing in Europe which exactly duplicated the conditions applicable to Eddystone, there has been considerable experience with advanced steam cycles as applied to once-through boilers. The basic principles and operating procedures are so similar as to require only moderate extrapolation. The design of Eddystone then has been based on this European background, together with the firm's own experience with high-pressure controlled circulation units utilising small-diameter tubing. In addition, the company carried out a broad research programme covering the problems associated with water purification and the metallurgy of high-temperature, high-pressure materials.

The design of this steam generating unit follows the general pattern of two-furnace units which were developed for capacities in excess of 200MW. As far as possible, it will be made up of standard components with which there have been many years of successful operating experience. The two notable exceptions are the once-through flow of water through the pressure parts and the design of the superheater for the high steam temperature combined with high pressure. This unit, as shown in Fig. 4, consists of two identical furnaces of the dry-bottom design, each fired with tangential burners situated in the four corners. Since there are two reheaters in this cycle, one can be associated with each furnace. In that way, each one can be controlled independently by burner tilt, thereby avoiding the necessity for spray desuperheating. This approach will make it possible to obtain the maximum cycle efficiency and at the same time provide constant reheat temperatures over a wide range of ratings. The steam temperature to the turbine will be regulated by proper proportioning of the water flow through the heating surfaces. Full consideration has been given, in the furnace design, to past operating experience with coals which will be available to this station. Sufficient cooling has been provided to avoid sticky ash deposits in the closely-spaced convection surfaces. The walls are completely covered with tangent tubes without exposed refractory, to facilitate cleaning with the aid of wall blowers.

The heat cycle adopted for Eddystone, by its nature and the amount of superheating and reheating to be done, indicated the necessity for a new approach to the arrangement of the heating surfaces. For example, 65 per cent of the heat absorption will take place in the superheaters and reheaters. Obviously, this indicated the desirability or necessity for a greater use of radiant superheating surface than is normally used with conventional designs for lower pressures and temperatures. This led to installing radiant superheaters on the upper furnace walls and the extensive use of widely spaced platens suspended in the upper portion of the furnace. Sufficient cooling surface has been provided in this manner to cool the gases to approximately 1650 deg. Fah. before leaving the furnace chamber at the top and entering the finishing stage of the superheater. Numerous studies were made of various arrangements of heating surface before adopting the one illustrated here. In these studies the following primary considerations were established :—(1) Each of the two reheaters should be controlled independently by burner tilt to maintain 1050 deg. Fah. over a 2 to 1 load range ; (2) the combination of radiant and convection heating surfaces must be such as to provide the best possible control characteristics over the expected load range ; (3) at the same time, consideration must be given to affording maximum protection to the metals in the pressure parts and the high-temperature superheater section, particularly under conditions which will exist during start-up as well as normal full-load operation ; (4) proper temperature differential between gas and steam must be established for efficient heat transfer in order to obtain the high boiler efficiency compatible with this heat cycle.

In the design which was finally adopted, the heating surface for the high-pressure circuit is the same in each half of the unit. Feed water enters the economiser and flows upward through tubes cooling the side walls of the convection pass. It is collected in a header on each side wall and directed through piping to the entrance of the tube circuits covering the lower furnace walls. These up-and-down circuits terminate in two headers situated at the centre of the front wall. The water which is collected at this point is then taken through piping to the convection surface at the top of the rear pass through tubing forming cooling means for the front and rear walls of the convection pass. The transition from water to steam takes place in this zone of low gas temperature and reduced heat transfer. Two separate circuits have been maintained up to this point for each furnace, making a total of four circuits, each with its own independent control system to maintain uniform metal temperatures and match the water flow to the heat absorption as required. Each circuit is then subdivided into two piping paths and directed to the radiant superheater forming the walls of the upper third of the furnace where it will pass through a series of horizontal tube circuits up to the roof. The final superheating is done in the platens in the upper front corner of the furnace and the convection pendant loops just beyond the furnace outlet. In this way superheating to 1200 deg. Fah. has been performed in a zone of minimum gas temperature compatible with the steam temperature from the standpoint of heat transfer, thus resulting in the minimum metal temperature. Heating the tubes around their entire circumference also serves to reduce the temperature stresses in the tube wall. These principles were considered

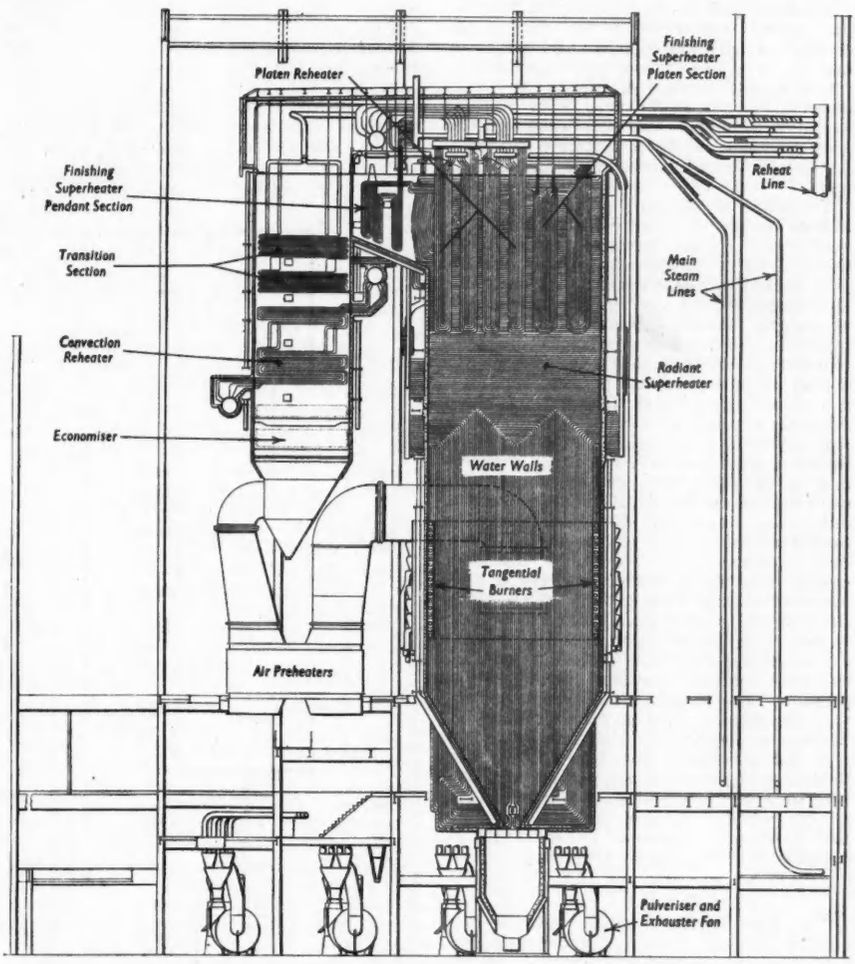


Fig. 4—Side elevation of supercritical pressure boiler designed by Combustion Engineering Incorporated, for the Eddystone power station

very important to ensure successful operation with this advanced cycle and the new alloys which are associated with it. The division into eight individually controlled circuits was justified by the same reasoning.

There is a complete reheater associated with each of the two furnaces. Steam from the turbine enters at the rear and is heated in two stages—first by convection in the rear pass immediately above the economiser, and then by radiation in the platens situated at the top of the furnace. The two reheaters are substantially the same, modified slightly only to suit the difference in steam temperatures from the turbine. The platen superheaters and reheaters are approximately 25in apart across the furnace width. Furnace gas will enter this surface at low velocity, about 25ft per second at peak load, and leave at about 37ft per second. The finishing superheater is spaced across the furnace on $9^{3}/_{32}$in centres.

There will be four Ljungström air heaters, two per furnace, and a symmetrical duct system arranged so that the air supply to the two furnaces may be controlled individually. Several years ago it became standard practice in the United States to support boiler units from overhead steelwork to simplify the supporting structure and to eliminate expansion problems. The same principle has been followed in the design of this unit.

The effort to eliminate any extraneous air leakage into the setting to permit efficient combustion with reduced excess air has led to the development of cubical expansion of pressure parts backed by a skin casing. The casing and tubes would expand together, being at the same temperature, thereby eliminating the need for expansion joints. These principles are being followed at Eddystone as far as possible. Of course, in the supercritical pressure cycle there is a constantly increasing tube temperature over the entire length of the circuit. This factor has required some modification to standard design details in order to achieve the overall objectives and, at the same time, provide for the free expansion of the individual tubes to allow for differential movement. Small-diameter tubes have been used for many years to line the walls of boilers employing the controlled circulation design. This led to the development of shop assembly of those tubes in large panels. Considerable savings have been effected in this way in shop handling, transport and field erection. To obtain minimum tube wall thicknesses and minimum stresses consistent with the high pressures and temperatures encountered with the Eddystone cycle, 1¼in diameter tubes will be used throughout the high-pressure circuits. It is not considered practicable to weld these tubes together continuously, as has been done with some controlled circulation units, because of the variable temperatures involved. On the other hand, it is planned to exploit fully the advantages of pre-assembly in the shop.

Control System

The most important single function of a control system for such an advanced steam cycle is the regulation of steam temperature. Not only does this apply to the final steam temperature to the turbine, but throughout the entire circuit if optimum metal temperatures are to be achieved in the pressure parts to ensure a long service life. The simplest form of once-through boiler is a single-tube circuit through which the water passes once and is superheated to the desired temperature at the outlet. Obviously, such an approach is impossible when dealing with a flow of 2,000,000 lb per hour. A multiplicity of circuits is required to achieve the desired objectives of small tube diameter and an overall pressure drop which can be economically justified. It was felt that there were two solutions to this problem. The first is to divide the circuit into comparatively small increments. Mixing headers can be provided at the outlet of each section and additional headers at the inlet of each succeeding section for redistribution of the water or steam to the parallel circuits. The second solution is the use of completely separate continuous circuits. Each of these could be controlled independently to proportion the water flow to the heat absorption as it might vary from tube to tube. Such a system would require a prohibitive quantity of control equipment.

Neither solution alone was considered practicable when consideration was given to the size of unit made up of two furnaces and the non-uniformity of heat absorption that experience has shown can be anticipated with such large areas. The design chosen for Eddystone is a combination of the two systems. Four independently controlled circuits are used from the economiser inlet to the outlet of the transition section, each consisting of a number of parallel tubes. At this point each system has been divided into two circuits, each with independent controls for water injection. Headers have been provided at four intermediate points where the flow through each circuit may be mixed thoroughly before passing to the next section of heating surface. The control devices are situated at these points. The combination of positive controls and mixing headers ensures a most uniform temperature distribution throughout the parallel circuits. The control system is divided into three primary functions: (1) Feed water flow and its distribution are directly associated with steam temperature regulation; (2) the by-pass system is regulated for the protection of the turbine and steam generator during starting and emergency conditions; (3) the combustion controls are interconnected to the turbine to satisfy the needs of generator output and pressure regulation. Expressed simply, the output of a turbo-generator is a function of the heat energy in steam supplied to the turbine throttle. The quantity of heat required for a given load is regulated by the combustion control equipment. It is then the function of the feed-water regulating system to proportion the water flow to the heat fired to provide the proper steam temperature at the turbine throttle.

Feed Water Regulation

The control system for feed water regulation can be described most clearly from a simplified diagram (Fig. 5), showing a single circuit through the steam generator. The objective of this system is to regulate steam temperature at three points in the circuit, namely, the outlet of the transition section, the outlet of the radiant superheater, and the outlet of the finishing superheater. While such a high degree of refinement may not be an absolute necessity, it was thought highly desirable for the steam conditions at Eddystone. The advantages anticipated are a more positive control of throttle temperature and a more complete control of metal temperatures throughout the entire steam generator.

The feed water flow to the economiser is regulated by a valve at the inlet which is designed and operated in such a manner that flow is a direct function of valve position. An anticipating impulse from steam flow is provided

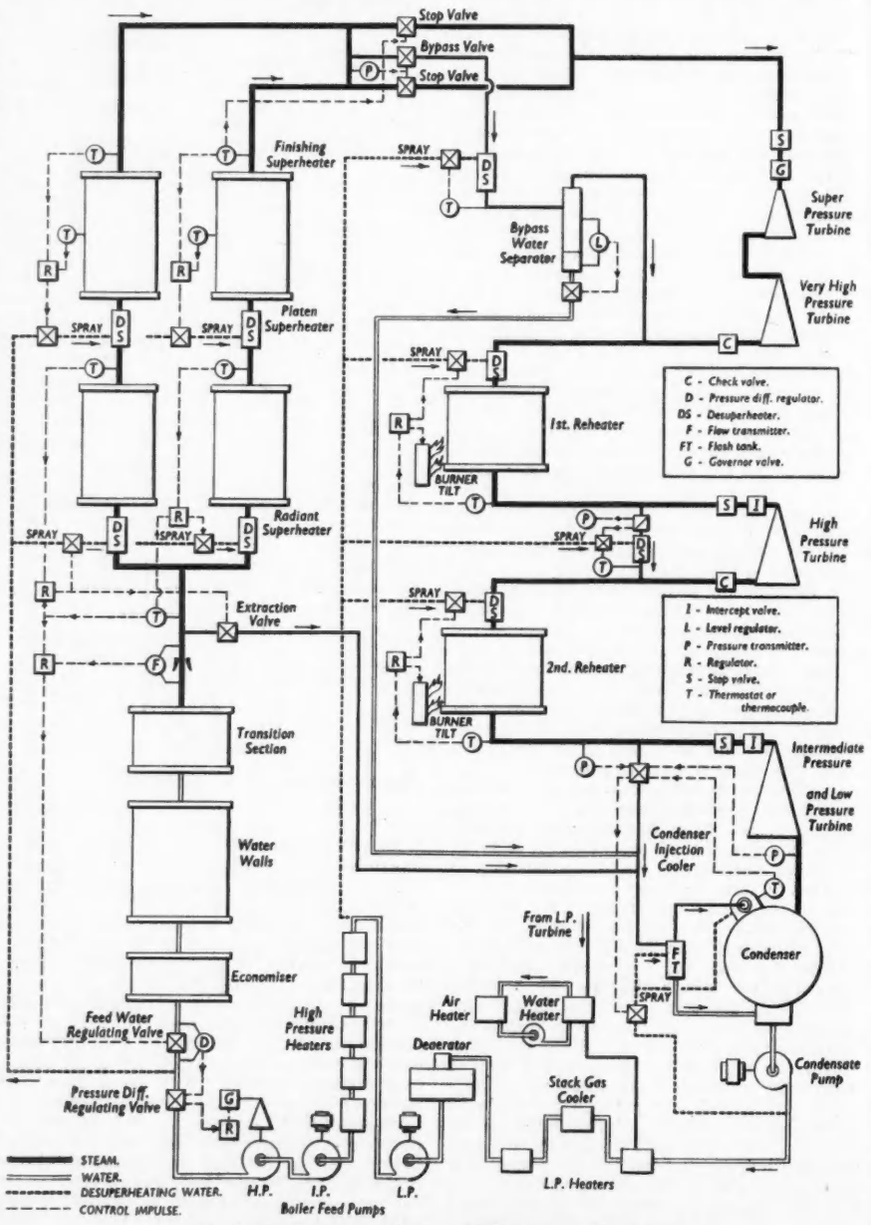


Fig. 5—Feed water flow diagram of Eddystone power station

by the pressure differential across a flow nozzle in the steam piping leaving the transition section. This will sense immediately any change in steam flow to the turbine. The final impulse comes from a thermostat at the same location correcting the feed water flow to maintain the desired steam temperature. Maintaining this temperature matches the feed water flow with the heat absorption in those heating surfaces. To obtain the desired control characteristics of the feed-water-regulating valve the pressure drop across the valve is automatically maintained constant by the pressure difference regulating valve immediately ahead of it. This valve compensates for variations in feed pump pressure and boiler pressure so that the feed water quantity depends exclusively on the setting of the feed water valve. The four pressure difference valves are interconnected with the speed regulators of both feed pump turbines to ensure an adequate supply for the entire unit and maintain the valve positions within the desired range.

The final steam temperature is regulated in two additional stages by means of water injection at the inlet of the radiant superheater and at the inlet of the platen section. There are in effect three-element controls. The first stage functions as follows :—(1) Water is taken from the feed line between the pressure difference valve and the feed-water-regulating valve. Because of the method of controlling the regulating valve, the pressure at this point is a direct function of load. For a given opening of the injection valve the quantity of water flow will be in direct proportion to the steam flow. An increase in steam flow automatically increases the quantity of injection water. (2) The thermostat at the outlet of the transition section provides an anticipating impulse to the injection valve on change of firing rate, which will produce a change in steam temperature at that point. (3) Final vernier regulation of the injection valve is accomplished through the thermostat situated at the radiant superheater outlet. The second stage functions in a similar manner. Injection water is taken from the same source as for the first stage. It is injected through the valve under control of the thermostats situated between loops of the platen surface and the outlet of the superheater. The position of the thermostats used for anticipation in both cases was chosen on the basis of calculations to determine optimum response characteristics.

Combustion Control

The integrated boiler turbine combustion control system regulates the turbine governor and the input of fuel and air supplies to the boiler to give the required generator output while maintaining a uniform steam pressure. Consideration is being given to the installation of two basic methods of control so that the operator may select either one through a transfer switch.

With the " direct energy balance " method, the input of fuel and air supplies to the boiler unit is regulated directly from the unbalance between required output and the actual generator output, while the turbine governor is controlled to maintain a uniform steam pressure. With this arrangement the boiler input is directly controlled to give the desired generator output and the turbine keeps in step with the boiler output. The " conventional " method regulates the turbine governor to give the required generator output, while the boiler input is basically controlled to maintain steam pressure. Combustion-rate anticipation is obtained from the generator output, together with the regulation applied to the governor motor. With this arrangement the boiler follows the turbine demand. In the supercritical pressure cycle utilising the once-through principle, the boiler and turbine must be closely integrated as a unit. The direct energy balance method of combustion control was developed by the Leeds and Northrup Company, of Philadelphia, to accomplish this objective through a more direct-acting control system.

As a further means of co-ordinating the overall operation of the unit, the combustion control system employs a " boiler-turbine governor " component, which is a new concept in the control of steam-electric units. It provides a means of changing the boiler-turbine output in an orderly manner and keeping the output within the capabilities of the boiler and the turbine. This governor component is sensitive to the generator frequency, which adapts the combustion control to the normal inherent regulation of the standard governor. The " boiler-turbine governor " integrates and supervises the operation of the boiler-turbine unit. It is composed of " load setter," " frequency," and " required load " servo units. These three servos are analogous to the synchronising motor, speed-sensitive element and turbine valve position of a standard turbine governor. It includes a rate-sensitive element to limit the maximum rate at which the required output can change, thus keeping within the response characteristics of the boiler-turbine equipment. The " boiler-turbine governor " is also provided with appropriate limiting and run-back actions to keep the required output within the capabilities of the boiler and turbine auxiliary equipment in service.

The limiting actions included in this governor block the travel of the " required output " servo. For example, when the fuel or feed water equipment in service is at a maximum or minimum limit, any further increase or decrease action is prevented. Similarly, when the fan equipment or governor valves reach an open limit, any increase travel is blocked. During load changes, should the generator output lag the required output by a preset deviation, appropriate limit action occurs to keep the boiler and turbine in step. In addition to these limits, suitable run-back actions are included to reduce the required output to preset limits on loss of one set of boiler feed pumps, or one set of fans. Similarly, the panel-adjusted " maximum-minimum limit setters " also function to keep the generator output within the range of the equipment in service. Likewise, a high steam temperature leaving the transition zone, as well as a high steam pressure, when using the direct energy balance method of control, will run back the " required output " servo accordingly. This " boiler-turbine governor " system is employed with either one of the two methods of control described below.

Direct Energy Balance Method.—When using the direct energy balance method of control, the fuel input to both furnaces is controlled to maintain a balance between required output and generator output. The fuel supplies to the two furnaces are automatically biased from the oxygen difference to compensate for differences in fuel quality and feeding conditions between the two furnaces. The air flow through each furnace is balanced initially against generator output, and this relationship is compensated automatically from the average oxygen content of the flue gases in both furnaces as required to maintain a uniform combustion efficiency. Each furnace air-flow controller regulates its respective pair of forced-draught fan inlet vanes, while a furnace pressure controller at each furnace adjusts its respective induced-draught fan dampers to maintain uniform furnace draughts. The standard turbine-governor motor receives its regulation from a steam-pressure controller, the control point of which is biased automatically during load changes to provide for the maximum response of the boiler-turbine unit.

Conventional Method.—With the conventional method of operation, the standard turbine-governor motor is controlled to maintain a balance between generator output and required output. The fuel input to both furnaces receives its initial regulation from changes in the generator output, together with the regulating impulses applied to the standard governor motor, as introduced through the " combustion-rate-anticipator " unit. This initial control action is modified, as required, by the steam-pressure controller to maintain a uniform steam pressure. The fuel supplies to the two furnaces are biased automatically from oxygen difference to compensate for differences in fuel quality or feed conditions between the furnaces. The air flow to each furnace, as well as furnace draught, is controlled in the same manner as in the direct energy balance method. With both methods of operation a panel-adjusted " minimum fuel and air flow " setter prevents reducing the boiler input below a preset adjustable limit upon complete loss of system load. Under this condition the turbine-by-pass system would function as required to accommodate the boiler output.

Turbine By-Pass System

It is the function of the turbine by-pass system to provide adequate cooling of all heating surfaces during cold starting and to permit the development of proper characteristics of steam before it is admitted to the turbine. The turbine by-pass system will be used during a hot restart of the boiler and for the protection of both boiler and turbine in the event of abnormal operating situations. Steam by-passes the turbine through the automatic super-pressure by-pass valve through the by-pass water separator, through the first reheater, through the automatic high-pressure by-pass valve and the second reheater, and finally through the automatic low-pressure by-pass to the condenser cooler and the condenser. When starting cold, water will be pumped through the entire boiler circuit to the by-pass system. It will be removed from the by-pass water separator and discharged to the condenser hot well through a flash tank.

The boiler stop valves will close from low-temperature or low-pressure impulses to prevent the admission of wet steam or water to the turbine. In addition to assisting with starting, the super-pressure by-pass valves serve as relief from over-pressure or over-temperature. The high-pressure and low-pressure by-pass valves are operated automatically, as well, to limit the pressure levels maintained in the by-pass system as desired. Three automatic water injection valves are provided to protect the boiler materials against over-temperature when the high-temperature steam is discharged into the system. The first valve is situated at the outlet of the super-pressure by-pass valve to limit the steam temperature entering the separator and first reheater to that which normally would exist in the cold reheat line at full load. The second one is situated beyond the high-pressure by-pass valve to limit the steam temperature to the second reheater in a similar manner. The third valve is associated with the condenser cooler for the protection of the condenser.

The entire turbine by-pass system is designed to permit the operation of the boiler at 30 per cent of its design capacity with full primary steam pressure and temperature with the turbine isolated completely. Safety valves would not function during this operation. Some heat will be recovered in feed water heating through normal extraction lines. Thus it will be possible to match the steam temperatures to those existing at the three admission points to the turbine before starting a hot machine. Following a turbine trip-out when the outage is expected to be of relatively short duration, it would be undesirable to cool down the steam generating unit and restart from a cold condition. In such a situation sufficient water will be passed through the circuits in the lower furnace for their protection in the burner zone. At the same time, the quantity allowed to pass through the high-temperature superheater tubing and main steam piping to the turbine will be reduced. This reduction will minimise the temperature shock to that material and recover temperature more quickly. It will be accomplished by extracting steam from the circuit at the inlet to the radiant superheater as indicated in Fig. 5. The control valve in the extraction line will be regulated automatically by the steam temperature leaving the radiant superheater. The function of this control will be to limit the reduction of temperature at this point as far as possible. Obviously, it will also function as a safety device in the event of loss of fuel input.

The high-pressure system and each of the reheaters will be completely protected by safety valves with full load-relieving capacity, although it is intended that the by-pass system shall operate in such a way as to minimise the occasions when the safety valves must operate. Naturally, without a boiler drum it will not be possible to place these valves strictly in accordance with the existing rules of the A.S.M.E. Boiler Codes, and some variations will be necessary following sound engineering principles in the development of a logical and balanced design.

(To be concluded)

Personal and Business

Appointments

MR. D. H. SCOTT has been appointed a director of Worthington-Simpson, Ltd.

MR. J. F. B. JACKSON has been appointed a director of P.I. Castings (Altrincham), Ltd.

MR. W. GRANT, A.M.I.Mech.E., A.M.I.E.E., has taken up an appointment with E. G. Brisch and Partners.

MR. H. E. LEVY, A.M.I.E.E., has been appointed chief engineer of Foster Transformers, Ltd., South Wimbledon, S.W.19.

MR. W. A. FISHER, M.I.Mar.E., has been appointed chief engineer of Heat Transfer, Ltd., 30, Church Street, Croydon, Surrey.

COSTAIN-JOHN BROWN, Ltd., has announced that Mr. Eric Mensforth, M.I.Mech.E., F.R.Ae.S., has been appointed a director.

KELVIN AND HUGHES (INDUSTRIAL), Ltd., has announced the appointment of Mr. J. R. Taylor as area engineer for the West of England.

MR. P. L. POCOCK, A.M.I.Prod.E., has been appointed general manager of the engineering division of Sheepbridge Equipment, Ltd.

THE ENGLISH STEEL CORPORATION, Ltd., states that Mr. J. P. Bennett and Mr. J. Cartwright have been appointed directors of Taylor Brothers and Co., Ltd.

PHILIPS ELECTRICAL, Ltd., has announced the appointment of Mr. S. Poole as regional manager of the newly formed south-west region of the company.

MR. E. O. WILKINSON has been appointed chief superintendent engineer of Canadian Pacific Steamships, Ltd., in succession to Mr. C. G. Ramsay, who has retired.

MR. W. A. J. SAYER has been appointed managing director of George Cohen Sons and Co. (South Africa) (Proprietary), Ltd., 53, African Homes Trust Building, Commissioner Street, Johannesburg.

THE BRITISH MECHANICAL RUBBER MANUFACTURERS' ASSOCIATION states that the following officers have been elected for 1957–58 :—Mr. W. E. Prior, chairman, and Mr. J. W. Mann, vice-chairman.

THE CENTRAL ELECTRICITY AUTHORITY has announced that Mr. P. J. Squire has left to join the technical operations department of the International Bank for Reconstruction and Development in Washington.

MR. C. S. GARLAND, president of the National Union of Manufacturers, has been reappointed by the Lord President of the Council for a further period of four years, as representative of the Crown on the governing body of the Imperial College of Science and Technology.

B.S.A. MOTOR CYCLES, Ltd., states that the power unit division is now under the guidance of Mr. Edward Turner, managing director of the automotive division. Mr. Denis J. Hardwicke has been appointed technical sales manager, responsible to Mr. W. L. Rawson, general sales manager.

SIMMONDS AEROCESSORIES, Ltd., Treforest, Glamorgan, has announced the following additions and appointments to its board of directors :—Mr. G. E. Bache, executive director and general manager ; Mr. S. H. Goss, Mr. C. J. Williams, Mr. P. Pehrson, Mr. A. Beard, and Mr. J. Burnell, executive directors.

THE BRITISH ALUMINIUM COMPANY, Ltd., has announced that Mr. H. Smith has been appointed laboratory superintendent at the Baie Comeau Works of the Canadian British Aluminium Company. Mr. W. McCamley will succeed Mr. Smith as superintendent of the routine laboratory at Kinlochleven with effect from June 1.

JOHN THOMPSON, Ltd., has announced that Mr. A. S. Dodd has been appointed London manager and has also been made a director of John Thompson Water Tube Boilers, Ltd. Mr. C. J. Howard has been appointed managing director of John Thompson Water Tube Boilers, Ltd. Mr. James Boyd has been appointed area manager, Belfast, of John Thompson, Ltd.

THE MINISTRY OF SUPPLY, with the agreement of the Secretary of State for Air, has announced the appointment of Air Commodore H. B. Wrigley as director of guided weapons (projects). It has also announced the appointment of Mr. L. G. Gale as director general of armament production in succession to Mr. V. A. G. Lambert, who is retiring from public service.

Business Announcements

HONEYWELL-BROWN, Ltd., states that it has opened a branch office at 5–7, New York Road, Leeds, 2.

MR. L. C. BINGHAM, sales director of the Venner Group of companies, has left this country by air on a business trip to Italy and Africa.

BIRLEC LTD., Tyburn Road, Erdington, Birmingham, 24, states that in future its interests in India will be handled by A.E.I. (India), Ltd., Calcutta.

JOHNSON AND PHILLIPS, Ltd., has announced that Mr. Frank Clifford, manager of the export department, has retired after thirty-five years' service with the company.

VENNER ACCUMULATORS, Ltd., states that it is now installed in a newly constructed, self-contained building situated behind the main factory at Kingston By-pass, New Malden, Surrey.

ROCOL LTD., Swillington, Leeds, states that its sales department has been reorganised and extended and that a northern sales area has been created under the management of Mr. S. Lumb.

MR. DAVID H. PEACE, manager of the plant sales division of the British Ceca Company, Ltd., has been awarded a travel grant to visit Australia under the auspices of the English Speaking Union.

MR. L. OLORENSHAW, chairman and managing director, and Mr. R. E. ALDRED, deputy managing director, of Taylor Woodrow (West Africa), Ltd., have left London by air to visit the company's Nigerian activities.

THE PLESSEY COMPANY, Ltd., and the PHILCO CORPORATION OF THE U.S.A., have announced the formation of a new company, Semiconductors Ltd., for the manufacture of transistors and other semiconductors in England.

KLOCKNER MOELLER ENGLAND, Ltd., has been formed to market in the United Kingdom electrical control gear manufactured by Klockner Moeller, Bonn. The company has offices at 4, Queen Street, Mayfair, London, W.1.

SIMMONDS AEROCESSORIES, Ltd., has announced the formation of a new subsidiary company, Firth Cleveland Instruments, Ltd., for the manufacture and marketing of instruments formerly produced by Simmonds Aerocessories.

ALBRIGHT AND WILSON, Ltd., Oldbury, Birmingham, states that the manufacturing activities in the past carried on by the company have been transferred to a wholly-owned subsidiary company, Albright and Wilson (Mfg.), Ltd.

THE ENGLISH STEEL CORPORATION, Ltd., and CANADIAN STEEL FOUNDRIES (1956), Ltd., have announced the formation of a new company in Canada. The new company, Canadian Steel Wheel, Ltd., will manufacture wrought steel railway wheels in Montreal.

D. NAPIER AND SON, Ltd., has concluded an agreement with PacAero, Inc., Santa Monica, California, under which the latter have for ten years the right to manufacture and sell the Napier "Spraymat" de-icing system for aircraft in the United States and their possessions.

F. W. KUBACH, Ltd., 12, Sylvan Road, London, S.E.19, has been formed as a limited company after forty-seven years' trading as a private firm. The company will be managed jointly by Mr. F. W. Kubach and Mr. H. G. L. Sambrook. Mr. P. J. Julian has been appointed company secretary.

THE SIMPLEX DAIRY EQUIPMENT COMPANY, Ltd., has announced that The General Electric Company, Ltd., has acquired a share interest in the company, and that the agricultural department of the G.E.C. has been transferred to the Simplex Dairy Equipment Company, Ltd., and its associated company, Agricultural Supplies (Cambridge), Ltd., at Cintra House, Cambridge.

Contracts

METROPOLITAN-VICKERS has received an order worth £170,000 from the National Coal Board for two four-rope tower-mounted friction winders for Bevercotes Colliery (East Midlands Division). The order covers a 2384 h.p. cage winder for No. 1 shaft and a 3466 h.p. skip winder for No. 2 shaft. They will be d.c. Ward-Leonard equipments, similar to those at Rufford, where the main pulley shaft is driven by two motors having armatures of barrel construction overhung from the ends of the shaft. The Ward-Leonard voltage variation is provided by the "Lamex" system, in which the field of the main Ward-Leonard generator is fed from a separate exciter set embodying an exciter with a laminated yoke and a field supplied from a magnetic amplifier. Very rapid response is combined with accurate voltage control.

ALEXANDER STEPHEN AND SONS, Ltd., has received from the British India Steam Navigation Company, Ltd., the order to re-engine the "Ormara" with a geared gas turbine and free piston gasifier installation. Four "G.S.34" free piston gasifiers will be manufactured by Alexander Stephen and Sons, Ltd., and the British Thomson-Houston Company, Ltd., is to build the reversing gas turbine, consisting of ahead and astern turbines and a reduction gearbox. The ahead turbine will be a six-stage reaction unit developing 4000 s.h.p. at 6800 r.p.m., and will be flexibly coupled to a single-stage impulse astern turbine.

Miscellanea

ALEXANDER RUSSELL SCHOLARSHIPS AT FARADAY HOUSE.—At the annual dinner of the Faraday House Old Students' Association, held at the Savoy Hotel last year, the Principal, Dr. W. R. C. Coode-Adams, announced the establishment of a new series of scholarships in memory of a former Principal, Dr. Alexander Russell, F.R.S. These scholarships cover all the tuition fees of a student throughout his period of training at the College, and they are in addition to the Faraday Scholarship (£200) and the Maxwell Scholarship (£100). The following candidates were successful in the 1957 examinations :—Alexander Russell scholarships, B. W. Estlin (Kent College, Canterbury), D. G. Clarke (Cheltenham College), C. M. Leech (St. Brendan's College, Bristol) ; Faraday scholarship, C. J. V. Smith (Bedales School) ; Maxwell scholarship, R. Emerson (Welwyn Grammar School).

DIESEL ENGINEERS AND USERS' ASSOCIATION.—The annual luncheon of the Diesel Engineers and Users' Association was held in London on May 2, with the president, Mr. K. H. Tuson, in the chair. Proposing the toast of "The Guests," Mr. Tuson reviewed the activities of the Association, and announced that the Percy Still Medal had been awarded to Mr. J. S. Tritton for his paper "The Special Requirements of Diesel Engines for Rail Traction." Mr. J. H. Pitchford replied on behalf of the guests and at the same time proposed the toast of "The Association." He expressed the opinion that the diesel engine was the most efficient means of converting liquid fuel into useful work and thought that the tax on diesel fuel should be remitted. Continuing, he remarked that many thought that increased consumption of diesel oil would create a serious unbalance in refinery throughput, but said that he felt certain the change-over in production was not an impossibility. Reverting to the economic use of fuels, Mr. Pitchford thought that gas oil should not be burnt in central heating systems, but that aid should be given to assist in the development of the use of heavier fuels for this purpose.

INSTITUTION OF ENGINEERS-IN-CHARGE.—The Minister of Power, Lord Mills, was the principal guest at the fifty-second annual dinner of the Institution of Engineers-in-Charge, which was held in London last Friday evening. Lord Sempill, the president of the Institution, was in the chair. Proposing the toast of "The Institution," Lord Mills spoke about the increasing energy requirements of the world and of this country in particular. Referring specifically to the nuclear power programme and to the aim to provide up to 6000MW by 1965, Lord Mills said that the fulfilment of that aim would undoubtedly furnish yet another example of this country's technical ability. Advances in technical education, he added, were now enormous compared with fifty years ago, and he believed that this country was well on the way to recapturing faith in itself. With their skill, enterprise and ability to invent and produce things, Lord Mills said, the people of this country could go forward into the future with confidence. The toast was acknowledged by the president and by Sir Harold Roxbee Cox, a vice-president of the Institution. A toast to "The Guests" was then proposed by Mr. L. Copeland Watts and responded to by Mr. G. A. Wilson, chief engineer of the Port of London Authority. Finally, the health of the president was proposed by Mr. W. J. Watkins, the Institution's chairman. In a brief reply, Lord Sempill expressed appreciation of the work of the Institution's officials, making special mention of the continuing devotion to all its affairs of Captain A. E. Penn, the honorary secretary.

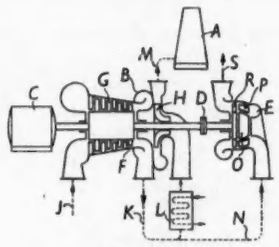
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

BLOWERS AND COMPRESSORS

771,638. June 22, 1955.—ROTARY COMPRESSOR PLANTS, Sulzer Freres, Societe Anonyme, Winterthur, Switzerland.

The invention relates to rotary compressor plants supplying air for metallurgical furnaces, and of the kind in which the compressor has a number of compressor stages and is driven at constant speed by an electric motor. According to the invention, a single-stage recuperation turbine with adjustable blading is used, and the recuperation air is supplied from an intermediate point in the compressor. In this way considerably smaller quantities of recuperation air are used—and therefore also correspondingly small losses arise. Furthermore, the losses arising from regulation of the plant are also decreased. The drawing shows a plant arranged to supply air for a furnace *A*. A compressor *B* is driven by a synchronous motor *C*, through a speed increasing gear. The shaft of the compressor is connected through a coupling *D* with a single-stage recuperation turbine *E*. The compressor has an intermediate stage *F*. Up to this intermediate stage—that is, in the low-pressure part—it is formed with axial-flow blades *G*, whereas in the



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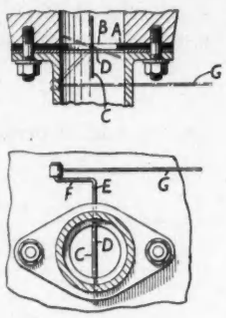
next following part—that is, in the high-pressure part—it has radial flow blades *H*. The air to be conveyed to the furnace is supplied to the compressor through a suction pipe *J*. After initial compression in the axial-flow stages *G* the air is withdrawn from the intermediate stage *F* through a pipe *K* and delivered through an intercooler *L* to the centrifugal stage *H*. After further compression in this high-pressure part the air passes finally through an outlet pipe *M* into the furnace *A*. A tapping pipe *N* branches off the pipe *K* upstream of the cooler *L*, and leads to the expansion turbine *E*. The amount of the air to be withdrawn can be regulated by inlet guide mechanism *O* provided with adjustable guide vanes *P*. The air is expanded in the single-stage *R*, which returns its power again to the compressor *B*, and finally leaves the recuperation turbine *E* through an exhaust pipe *S*. The regulation of the whole plant is extremely simple. It is sufficient to regulate the amount of air to be expanded in the recuperation turbine *E* by adjusting the guide vanes *P*. In this way the pressure and quantity of the air delivered by the compressor plant is determined while the whole plant runs at constant speed. The operation is illustrated by a pressure-volume curve, also shown in the specification.—*April* 3, 1957.

INTERNAL COMBUSTION ENGINES

771,649. August 25, 1955.—A FUEL ECONOMISING DEVICE, Arthur George Moorwood, 36, Victoria Road, Brentwood, Essex, and Stanley Moorwood, 16, Upper Park Road, New Southgate, London, N.11.

The invention relates to a fuel economising device for internal combustion engines and more particularly concerns a device which is operable manually by the driver when the engine is idling. Referring to the drawing, the device is fitted between one or more of the cylinder inlet branches of an induction manifold and the associated cylinder inlets in the cylinder block. As shown clearly in the upper view it comprises a plate or joint *A* of thin layers or laminations of metal or heat-resisting sheet material. The laminated plate has a hole or opening *B*, which is slightly smaller than a disc valve *C* fitted to a spindle *D* which is rotatably supported at one end in a hole in the laminated plate, and which extends up through the plate *A* as indicated in the lower view at *E*. It terminates in a cranked portion *F* connected to a push-and-pull rod *G*. The arrangement is such that the valve *C* is movable from a fully open, full-line position, in which it permits a maximum flow of mixture to the cylinder to a partially closed position indicated in chain dotted lines in which it permits only a predetermined minimum flow of mixture to pass to the cylinder, which is sufficient to ensure that the engine will continue to run without stalling. Alternatively, the valve can be moved to



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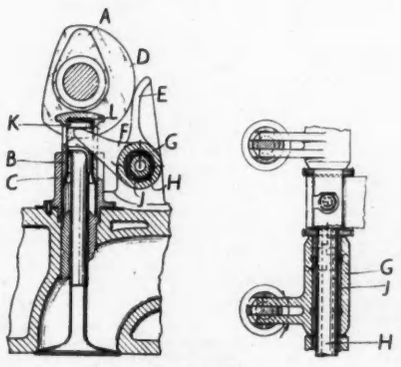
a fully closed position. The device of this invention is shown fitted to two cylinder inlets of a four-cylinder engine. It is desirable that fully balanced conditions should be obtained and in this respect it is preferred to fit the device to two cylinders of a four-cylinder engine or to three cylinders of a six-cylinder engine, and so on.—*April* 3, 1957.

772,771. April 7, 1955.—VALVE GEAR FOR HIGH-SPEED ENGINES, Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

The invention concerns valve gear, particularly for high-speed internal combustion engines, of the kind in which a lift valve is driven positively in both directions by cams, one of which drives the valve in one direction through the intermediary of a two-armed lever, and the other drives the valve in the other direction, preferably directly. As shown in the drawing the valve, which may be an admission or exhaust valve of an engine, is guided in a two-part bush in the cylinder head. The valve is driven by a conventional cam *A* which directly engages a valve tappet *B* guided in a bush *C* on the cylinder head and with a further cam *D* against which bears one arm *E* of a two-armed lever *E* and *F*. The arms are rigidly connected together by a hub *G* which is mounted on a shaft *H* with the interposition of an eccentric bush *J* having an eccentricity of less than 0·5mm. As may be seen from the right-hand view, the arm *F* is in the form of a fork engaging lateral grooves or milled recesses in a part of the valve stem which is of increased diameter and bear against a collar *K*. Interposed between the upper face of the collar and the bottom of the tappet is an exchangeable disc *L* which serves to make up



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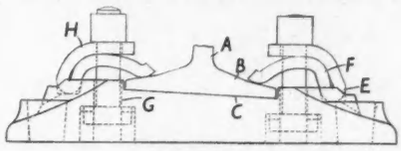
play existing between the tappet *B* and the cam *A* when the valve is closed. The tappet is provided with two longer openings for the passage of the arms and with two shorter openings on the opposite side, so that the arms can freely rock about their axis on movement of the valve. In order to restrict structural height and weight, the valve stem is made relatively short. By adjusting the eccentric bush *J*, play between the cams *A* and *D* and the lever arms *E* and *F* can be effectively taken up.—*April* 17, 1957.

RAILWAY ENGINEERING

772,821. February 22, 1955.—SECURING RAILS TO RAIL CHAIRS, George Turton, Platts and Co., Ltd., Meadowhall Road Works, Wincobank Sheffield, 9. (*Inventors: John Clifford Cowen and Eli Penn.*)

In the drawing, one rail clip is shown in the operative clamped position, while the other at the opposite side of the rail is not clamped down. *A* is a rail supported by its foot *B* on a recessed seating face *C* of a base plate secured to a sleeper by screws or bolts. In the base plate at opposite sides are pockets *E* for locating the outer ends of rail clips *F* and holes *G* for receiving clip securing bolts. Each rail clip is formed from a bar bent into U-shape and folded upon itself to provide a curved overlying length *H* in contact with a complementary curved underlying length and with the rounded fold constituting one end of the clip, which is accommodated in the locating pocket. When the clip *F* is placed in position it will be seen that the contacting overlying and underlying clip



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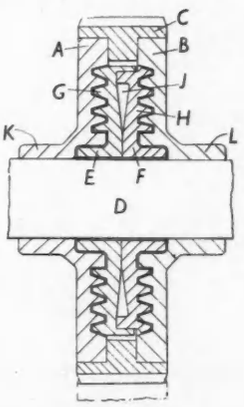
limb lengths provide an arch-like formation so that when the clip is secured by its bolt it is constrained by a slight flattening effect of the arch. In use, when slight movement of the rail takes place under running conditions, the rail engaging end of the clip formed by the two curved free ends of the limbs makes slidable engagement with the flange or foot of the rail.—*April* 17, 1957.

POWER TRANSMISSION

771,903. February 21, 1955.—FRICTION CLUTCH, Thomas Hindmarch, Lindo Lodge, Stanley Avenue, Chesham, Buckinghamshire.

The invention relates to friction clutches and in particular clutches incorporated in gear wheels, its object being to provide a pinion having incorporated with it a friction clutch in which adequate concentricity is maintained when the clutch is in the disengaged condition. A longitudinal section of a pinion having a separate toothed gear ring is given. The two outer clutch members *A* and *B* are connected by a toothed gear ring *C* by means of which a drive to or from the shaft *D* may be transmitted when the clutch



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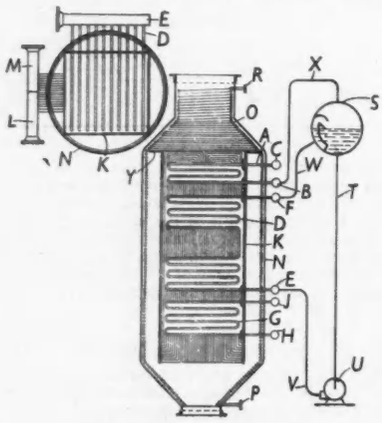
is engaged. The inner clutch members *F* and *E* are provided with cylindrical projections *G* and *H* which have splines which engage the shaft *D* so as to be free to move longitudinally away from one another to contact the outer members *A* and *B* to transmit the drive when pressure fluid is introduced into the pressure cavity *J*. The outer members have cylindrical projections *K* and *L* which form the bearings upon the shaft *D*, and completely independently of the clearances around the splines in order that free longitudinal movement may be made to engage and disengage the clutch. The outer member or gear wheel does not rotate upon the cylindrical portions *E* and *F* of the inner members, but upon the shaft independent of the movable portions. The specification also shows a form of construction in which the teeth of the pinion are formed integral with each of the outer friction members and which are held rigidly together by the screw thread upon each part.—*April* 3, 1957.

STEAM GENERATORS

772,991. September 7, 1955.—FORCED RECIRCULATION STEAM GENERATORS, La Mont International Association, Ltd., 42, Leicester Square, London, W.C.2. (*Inventor: Karl Hans Reppel.*)

The invention relates to steam generators of the forced recirculation type, in which a circulating pump is used to maintain a flow of boiler water at saturated steam temperature through the heated tube elements. Its object is to provide an improved construction which utilises the heat entrained in waste gases from internal combustion engines or gas turbines. Referring to the construction shown in the drawing, the

gases pass over the boiler heating surfaces, comprising a superheater *A*, with inlet header *B*, and outlet header *C*, evaporator *D* with distributor header *E* and collector header *F*, and economiser *G*, with inlet header *H* and outlet header *J*. The heating surfaces are bounded on their four sides by baffle walls *K* constructed from closely pitched tubular elements in parallel formation. These tubular elements emanate from a distributor header *L*, and form in turn the four baffle walls, and return to a collector header *M*. The steam generator heating surfaces are contained within a pressure-resistant casing *N*, of cylindrical form.



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To protect the pressure-resistant casing from the hot gases a helically wound tubular element *O* with inlet connection *P* and outlet connection *R*, through which boiler water at saturated steam temperature is circulated, is fitted to the inside wall. Boiler water at saturated steam temperature passes from the steam and water drum *S* through suction pipe *T* to the circulating pump *U*, and discharges through pipe *V* into the evaporator distributor header *E*, passing through the evaporator heating surface *D*, absorbing the heat contained in the gases, to collector header *F*, and discharges into the steam and water drum *S* through pipe *W*. In the same manner, the circulating pump *U* supplies boiler water to the tubular elements forming the baffle walls *K* and is returned from the collector header to the steam and water drum. The helical element *O* is supplied with boiler water in a similar manner. Saturated steam leaves the drum *S*, passes through the pipe *X* to the superheater, and thence to the power plant. The small circular segments between the casing *N* and the baffle walls *K* are fitted with heat-resistant plates *Y*, arranged in the form of dampers, which can be regulated to by-pass a proportion of the gases during low loads and to vary the boiler output. Modified arrangements of headers are also shown in the specification.—*April* 17, 1957.

Launches and Trial Trips

HEMISINUS, oil tanker; built by Cammell Laird and Co., (Shipbuilders and Engineers) Ltd., for Shell Tankers, Ltd.; length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, summer draught 29ft 9in, deadweight 18,000 tons; thirty-three cargo oil compartments, one main cargo pump room; two 550kW turbo-alternators, one 200kW diesel driven generator; one set of double reduction geared compound turbines, 8250 s.h.p., two Babcock and Wilcox integral furnace watertube boilers supply steam at 500 lb per square inch and 800 deg. Fah.—Launch, February 15.

PEGASUS, cargo liner; built by the Furness Shipbuilding Company, Ltd., for the Sociedad Transoceanica Canopus S.A. Panama; length between perpendiculars 480ft, breadth moulded 66ft, depth moulded to upper deck 42ft 6in, deadweight 15,900 tons on 31ft 3½in summer draught; five holds, capacity 818,500 cubic feet, fifteen derricks, electric winches; three 150kW diesel driven generators, one 50kW steam driven generator; N.E.M.-Doxford, single acting, two stroke, opposed piston, oil engine, five cylinders 670mm diameter by 2320mm combined stroke, 5500 b.h.p. at 115 r.p.m.—Launch, February 15.

CRESTBANK, cargo liner; built at Belfast by Harland and Wolff, Ltd., for Andrew Weir Shipping and Trading Company, Ltd.; length between perpendiculars 450ft, breadth moulded 62ft 6in, depth moulded to upper deck 38ft 6in, gross tonnage 6300; five main cargo holds, one 25-ton, two 10-ton, twelve 5-ton and two 3-ton derricks, electric winches; three 175kW diesel driven generators, one 20kW diesel driven emergency generator; two auxiliary boilers; Harland and Wolff diesel engine, six cylinders 620mm diameter by 1870mm combined stroke, 118 r.p.m.—Launch, February 15.

ABERDEEN MERCHANT, trawler; built by Alexander Hall and Co., Ltd., for Aberdeen Motor Trawlers, Ltd.; length between perpendiculars 113ft, breadth moulded 25ft, depth moulded 12ft 6in; fish room capacity 6700 cubic feet, electric trawl winch barrel capacity 650 fathoms of 2¼in warp, 115 h.p. motor, one 95kW diesel driven winch generator; Mirrlees mark KSDM-6 diesel engine, 760 b.h.p. at 250 r.p.m.—Launch, February 18.

Catalogues and Brochures

LEAD DEVELOPMENT ASSOCIATION, Eagle House, Jermyn Street, London, S.W.1.—Information pamphlet on the "Applications of Lead," entitled "Lead in Atomic Energy." Details are given of some of the uses to which lead is put for protective purposes when handling radioactive materials.

BRITISH NYLON SPINNERS, Ltd., 25, Upper Brook Street, London, W.1.—Twenty-page booklet giving details of the increased uses to which nylon ropes are being put. These ropes are claimed to be nearly twice as strong as a natural fibre rope of the same size and weigh considerably less.

COPELAW, Ltd., Mowden Hall, Darlington, Co. Durham.—Leaflet illustrating the "Carricut" portable hydraulic shear which can be transported and operated by one man. It is claimed that it will cut steel or iron rods, wire ropes and cables, and chains, quickly and cleanly, without flash.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., Rugby.—Booklet No. 13023, entitled "Electronic Control of Resistance Welding." A representative selection of resistance welding control equipments is illustrated, together with some of the installations where these and similar equipments are in service.

THE SOLARTRON ELECTRONIC GROUP, Ltd., Thames Ditton, Surrey.—Leaflet describing type BA564 eddy current non-destructive test set, a laboratory instrument for basic research in ferrous and non-ferrous metals, or for use by unskilled operators where continuous inspection of metal stock is required.

TITANIUM METAL AND ALLOYS, Ltd., 2, Metal Exchange Buildings, Leadenhall Avenue, London, E.C.3.—Illustrated brochure giving details of the physical and mechanical properties of titanium, its resistance to corrosion and some of its applications. Particulars of the products available are also included.

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., 95, Aldwych, London, W.C.2.—Booklet No. 518, illustrating and describing the use of aluminium as a cable sheathing material. Tables are included, giving current ratings of aluminium sheathed paper cables and a final chapter describes installation methods.

SUBMARINE CABLES, Ltd., Mercury House, Theobald's Road, London, W.C.1.—Illustrated brochure describing the cableship "Ocean Layer." This ship can carry up to 1100 nautical miles of the latest type deep-sea coaxial telephone cable, equivalent to 1875 nautical miles of average size deep-sea type telegraph cable.

ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHARLEROI, Belgium.—Illustrated brochure describing low-voltage distribution centres for indoor and outdoor installations, with withdrawable air-break circuit breakers, also an illustrated brochure giving details of high-voltage unit cubicles, indoor and outdoor types.

GILBERT GILKES AND GORDON, Ltd., Kendal, Westmorland.—Handbook entitled "On the Development of Water Power," giving technical details of the range of water turbines manufactured and much general information on modern water turbine practice. Tables list the characteristics of standard Gilkes turbines.

FERRANTI, Ltd., 21, Portland Place, London, W.1.—Publication entitled "Applications of Ferranti Computers," consisting of a number of essays, written by those who prepared the work for an electronic computer. The brochure covers a wide range of computer applications in science, industry, commerce and administration.

TECHNICAL CERAMICS, Ltd., Wood Burcote Way, Towcester, Northants.—Leaflet describing the "Sonotone" ceramic pick-up head for record players. Barium titanate, from which the reproducing element itself is made, is impervious to distortion through humidity and temperature changes. Performance and installation figures are included.

NATURAL RUBBER DEVELOPMENT BOARD, Market Buildings, Mark Lane, London, E.C.3.—Bulletin No. 11, entitled "Rubber in Roads—and Runways," describing the laying of rubberised airstrips at an Australian air station; also a brochure entitled "Rubber in Roads," describing the properties of rubberised bitumen and its preparation and use.

THE STANDWELL EQUIPMENT COMPANY, Ltd., Worple Mews, Worple Road, London, S.W.19.—Fourth edition of a catalogue entitled "Marking Devices." This is an abridged catalogue of steel stamps, type, and marking machines. Special attention is drawn by the manufacturers to the dial-type name-plate marking machine which has recently been introduced.

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS, Ltd., Rugeley, Staffordshire.—Publication entitled "Industrial Electronic Equipment," describing some of the equipment manufactured for speed drives, regulators for electrical machines, process control equipment, photoelectric equipment, resistance welding control equipment and protective and supervisory equipment.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, May 10.—BRISTOL AND WEST OF ENGLAND BRANCH: Grand Hotel, Bristol, "Presentation Lighting," C. R. Passmore, 8 p.m. ★ STOKE AND CREWE BRANCH: Grand Hotel, Hanley, Stoke, "Earth Loop Testing," E. H. Lea, 7.30 p.m.

Tues., May 14.—BOURNEMOUTH BRANCH: Grand Hotel, Firvale Road, Bournemouth, Annual General Meeting, 7.15 p.m.

BRITISH INSTITUTE OF MANAGEMENT

Wed., May 22.—Management House, 8, Hill Street, London, W.1, "Planning Wide Range Production for Fluctuating Demand," T. P. Child, 6.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, May 10.—S. MIDLANDS SECTION: Ministry of Supply College of Electronics, Malvern, "Broadcasting Aerials," H. V. Sime, 7 p.m.

Wed., May 22.—LONDON MEETING: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Barium Titanate and its Use as a Storage Device," G. Campbell, 6.30 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., May 18.—LONDON MEETING: Caxton Hall, Caxton Street, Westminster, London, S.W.1, Annual General Meeting, 6 p.m.

CHADWICK PUBLIC LECTURES

Thurs., May 16.—LONDON MEETING: Royal Society of Health, 90, Buckingham Palace Road, London, S.W.1, "The Conservation of Water Supplies," Herbert Addison, 5.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., May 14.—LONDON MEETING: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, Annual General Meeting, 5.30 p.m., followed by "Changing Tastes in Design," Paul Reilly, 6.30 p.m. ★ LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, Annual General Meeting, 6 p.m.

INCORPORATED PLANT ENGINEERS

Tues., May 14.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "High-Pressure Hydraulic Pumps and their Associated Control Valves," A. M. Worswick, 7.15 p.m.

Wed., May 15.—KENT BRANCH: King's Head Hotel, High Street, Rochester, "Safety and the Factories Act," V. B. Jones, 7 p.m.

'INSTITUTE OF NAVIGATION

Fri., May 17.—LONDON MEETING: Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation and the Airlines," E. W. Pike, 5.15 p.m.

INSTITUTE OF PHYSICS

To-day, May 10.—LIVERPOOL AND N. WALES BRANCH: Department of Electrical Engineering, University of Liverpool, "Rocket Exploration of the Upper Atmosphere," H. S. W. Massey, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, May 10.—S. WALES GROUP: South Wales Institute of Engineers, Park Place, Cardiff, "The Service Methods and Construction of Commercial Vehicles," C. H. Rowley, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., May 14.—ORDINARY MEETING: Great George Street, Westminster, London, S.W.1, James Forrest Lecture, "Large Telescopes," R. V. D. R. Woolley, 5.30 p.m.

Tues., May 21.—STRUCTURAL AND BUILDING (B) MEETING: Great George Street, Westminster, London, S.W.1, "Brick and Masonry Arch Bridges: An Investigation," C. S. Chettoe and William Henderson, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., May 14.—N. IRELAND CENTRE: Engineering Department, Queen's University, Belfast, Annual General Meeting, 6.30 p.m.

Wed., May 15.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "A Survey of Transistor Circuit Techniques," 5.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION: Visit to Belling and Co., Enfield, "Fire and Cooker Manufacture," 2.30 p.m.

Thurs., May 16.—S.W. SUB-CENTRE: Electricity Showrooms, New George Street, Plymouth, "Age and the Incidence of Fires in Electrical Installations," L. Gosland, 3 p.m.

Sat., May 18.—RADIO AND TELECOMMUNICATION SECTION: Visit to B.B.C. and I.T.A. Television Transmitting Stations, 9.15 a.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, May 10.—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, James Clayton Lecture, "Projection Planetarium and Shell Construction," Walther Bauersfeld, 6 p.m.

Tues., May 14.—LONDON GRADUATES' SECTION: 1, Birdcage Walk, Westminster, London, S.W. 1, Annual General Meeting, "Modern Marine Propulsion," A. R. Hopwood and R. S. Saunders, 6.30 p.m.

Thurs., May 16.—MIDLAND BRANCH: St. Mary's Hall, Coventry, "Mechanical Breathing Machines," G. T. Smith-Clarke, 6.30 p.m.

Fri., May 17.—GENERAL MEETING IN CONJUNCTION WITH THE LUBRICATION AND INTERNAL COMBUSTION ENGINE GROUPS: 1, Birdcage Walk, Westminster, London, S.W.1, "Diesel Engine Lubricants: Their Selection and Utilisation, with Particular Reference to Oil Alkalinity," A. Dyson, L. J. Richards and K. R. Williams, 6 p.m.

Sat., May 18.—LONDON GRADUATES' SECTION: Visit to the Generating Plant at Bankside Power Station, 9.30 a.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., May 16.—LONDON MEETING: Geological Society of London, Burlington House, Piccadilly, London, W.1, Annual General Meeting, 4 p.m.

INSTITUTION OF NAVAL ARCHITECTS AND INSTITUTE OF MARINE ENGINEERS

Sat., May 18.—S. JOINT BRANCH: Visit to Saunders-Roe, Ltd., Cowes, Isle of Wight.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., May 15.—WOLVERHAMPTON GRADUATE SECTION: Wolverhampton and Staffs Technical College, Wulfruna Street, Wolverhampton, "Gas Turbines—Basic Principles and Production Difficulties," C. E. Wurr, 7.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., May 14.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "New Techniques in Manufacture," W. A. Baker, 7 p.m.

ROYAL METEOROLOGICAL SOCIETY

Wed., May 15.—JOINT DISCUSSION MEETING WITH THE ROYAL STATISTICAL SOCIETY: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Analysis of Geophysical Time Series," opened by J. M. Craddock, H. Charnock and S. Rushton, 5.15 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Tues., May 14.—CHEMICAL ENGINEERING GROUP: 14, Belgrave Square, London, S.W.1, Joint Meeting with Plastics and Polymer Group, "Some New Chemical and Physical Aspects of Polyester Resin Technology," L. H. Vaughan, 5.30 p.m.

Thurs., May 16.—ROAD AND BUILDING MATERIALS GROUP: Visit to the Radiochemical Centre, Amersham, Bucks, 2.30 p.m.